AIR FORCE JOURNAL of LOGISTICS

Volume XXII, Number 3 | Fall 1998 | AFRP 25-1

ARTICLES

DEPARTMENTS

The *Air Force Journal of Logistics* (*AFJL*), published quarterly, is the professional logistics publication of the United States Air Force. It provides an open forum for presenting research, innovative thinking, ideas and issues of concern to the entire Air Force logistics community. It is a nondirective publication published under AFI 37-160V4. The views and opinions expressed in the *Journal* are those of the author and do not necessarily represent the established policy of the Department of Defense, Department of the Air Force, the Air Force Logistics Management Agency or the organization where the author works.

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Fightn' N' Stuff

Wing Commander David J. Foster, RAF

I git thar fustest with the mostest men.[1]

—Lieutenant General Nathan Bedford Forrest

The means of victory is concentration . . . . There are only four key factors to think about if we seek success in concentration. Thinking about these factors is not a simple task. For although few in number, their impact, dynamics and interdependencies are hard to grasp.

To win in battle we must concentrate combat power in time and space. Strategy and tactics are concerned with the questions of what time and what place; these are the ends, not the means. The means of victory is concentration, and that process is our focus here. There are only four key factors to think about if we seek success in concentration. This is not a simple task. Although few in number, their impact, dynamics and interdependencies are hard to grasp. This is a problem as much of perspective as of substance. It concerns the way we think, as much as what we are looking at. The factors are not functions, objects or even processes. They are best regarded as conditions representing the nature of what we are dealing with in seeking concentration. They are:

Variability - Uncertainty - Synchronicity - Complexity

In this analysis we take a systems view of the world to look at basic concepts, to arrive at a way of looking at things, rather than to present a set of answers. The ideas are fuzzy, so we use simple words and pictures. Simple words like *stuff*. This means fuel and spares . . . bullets, bombs and missiles . . . tools, machines, power and water . . . food, maps and toilet paper . . . and anything else we need to keep us in the fight. The use of simple language is not a trivialisation; it forces us to focus on essentials. One of the problems we face is the way we think. Here we attempt to look at things from a new angle, to break out of the old frame of reference, to think out of the box, to reflect on the basics.

In the widest sense of the term, which is how we will use it, logistics is the crucial enabler for operations. However, logistics on its own is not worth talking about. It is not independent. It exists only as one-half of a partnership that governs the success or failure of concentration. Our aim here is to develop a simple, holistic description of the partnership of operations and logistics, to provide a perspective for effective thought and action.

First we explore the fundamental nature of the partnership. We start at the point where operations and logistics meet, then step down into the world of stuff to take a look at what happens there. Once we have a picture of the basic mechanics of logistics we move on to look at what links activity in the world of operations to work in the world of stuff. We then use our new perspective to examine how the particular nature of a military force governs the way things happen in practice. Here we look at the differences and similarities in the structure and dynamics of the partnership in the separate cases of land, maritime and airpower, to determine how the partnership works. In conclusion we offer a view of what really matters in managing the partnership to achieve our goal of effective concentration.

. . . logistics governs the tempo and power of operations. For us, and for our enemy. We have to think about the partnership of operations and logistics because it is a target. A target for us, and for our enemy.

Why is understanding this so important? Logistics governs the tempo and power of operations. For us, and for our enemy. We have to think about the partnership of operations and logistics because it is a target. A target for us, and for our enemy. Like any target, we need to fully understand its importance, vulnerabilities and critical elements to make sure we know what to defend and what to attack. All military commanders, at all levels of command, rely on the success of this partnership. How well they understand it will make a big difference concerning how well it works for them and how well they work for it.

A real knowledge of supply and movement factors must be the basis of every leader's plan; only then can he know how and when to take risks with those factors, and battles are won only by taking risks.

—Field Marshall A. C. P. Wavell

Real knowledge in this context is deep knowledge, not simply how long it takes a force to move from A to B, or the numbers of weapons needed to take on a particular enemy strength; but an understanding of the likely behaviour and response of the logistics system, in the face of the real demands, of real operations, as they develop and as they are executed. So this is a tale of two systems and how they work together as one: operations and logistics—*fightin' n'stuff*.

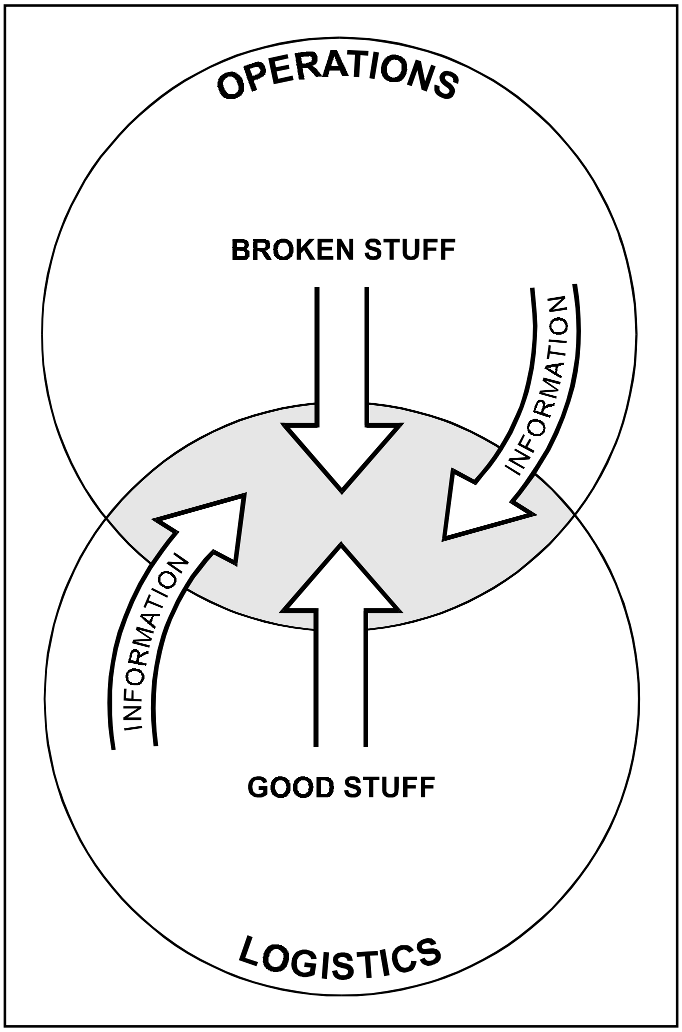

Figure 1. Operations and Logistics

Part One—The Nature of Fightin' n' Stuff

Operations and logistics sit alongside each other; they overlap (Figure 1). Imagine the overlap as the area where fighting machines are loaded before launch and recovered after an engagement. Between the two systems there is an interface where information and objects are exchanged, in both directions. This *communication* takes time and energy. Logistics gives operations the stuff needed to bring a weapon to readiness. Stuff includes fuel and things that go bang, but also serviceable parts for the weapon and personal kits for its operators. Lack of stuff usually gets the most attention; it is what makes the most noise, where the pain seems to come from, where failure first becomes apparent. But often it is not where we find the real cause of failure; lack of stuff is the symptom, not the disease.

Logistics gives operations information. We sometimes overlook the importance of getting this right, and then we fail. To be effective, operational planning must have a good indication of how the logistics system is likely to perform under load. But operators are not mind readers, they have to be told what can and cannot be done.

Even less well understood is how much our success depends on operations getting stuff and information back to logistics. Firstly, a lot of stuff is scarce and critical. Broken stuff of this kind is a potential resource. The quicker we mend it and get it back into circulation the higher our readiness states will be. Consider the priority given to operational turnarounds to get an aircraft fuelled and armed and back online for the next mission. The same urgency is needed in regenerating critical aircraft components, for exactly the same reasons. Secondly, logistics needs information. Some of our stuff runs out of life and some we break. Some stuff we consume, like fuel. Timely and accurate information on actual and potential usage, in terms of breakage, failure and consumption, is important. Without this feedback on changing circumstances the logistics system cannot respond and adapt and support performance will deteriorate.

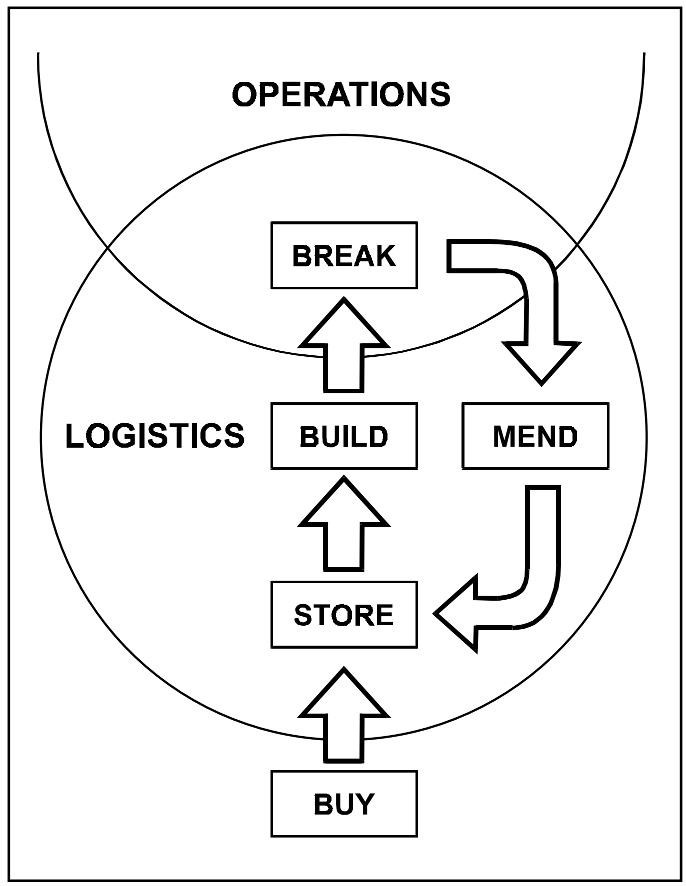

Figure 2. Processes

Now we have a simple view of the key *transactions* between operations and logistics. But what happens inside the two systems? What drives the transactions? Our next step is to take a close look at the world of stuff.

To get answers we need to look at logistics as a complete system, and we need to stand well back to get the whole picture. We need to think about: what the system is for, what it includes, what it produces, what happens inside it and what is needed to feed it, how it is put together, what it handles and how it works. The fundamental purpose of logistics in our context is to enable the focusing of combat power, in time and space. That is what it is for, but what is it? This analysis proposes that we can see it as just a few very simple processes (Figure 2).[2]

Clearly, before we can do anything we have to bring new stuff into the system from outside: we BUY. This is a fundamental process, but we are concerned in this discussion with the problems of fighting with the stuff we have already got our hands on. We will not consider here the planning, budgeting and programming issues, the *shopping* problems, important though they are.

What do we do with stuff once we have it? We MOVE it around the system. When it is not moving we STORE it. This all takes people, facilities, transport, management and time. We MEND stuff we have broken and stuff that fails. This takes skills, tools, spare parts and time. And for complex stuff each different piece usually needs its own very specific skills, tools and test equipment. We put stuff together to BUILD more complicated stuff. Again this takes skills, tools and equipment that are specific to the task and more time. Each process is very simple. It is true that within the MEND box we find very skilled and intricate engineering activity, but in essence all that clever work does is generate more demands for more stuff. It is tempting to identify a separate process showing us REPLACING stuff we have consumed, but this is merely a special case of the general cycle. When we consume stuff, the flow is only one way. There is one caveat. Figure 2 shows operations as the only source of broken stuff. This is just a schematic simplification. Stuff also breaks and is consumed in the logistics system.

These are simple processes. What makes logistics such a puzzle is that we put hundreds of these simple processes into a complex network of relationships and then populate the network with thousands of families of components, subsystems and parts all moving around the network from one simple process to another, sharing pathways, hitting bottlenecks and waiting. Waiting for parts to arrive to complete a set and fill the last hole in a component. Waiting for repair facilities to be free.

Consider what this means, at each stage. First we have to find all the parts we need and get them together in one place. Then we have to put them together as a set. This takes time, tools and skill.

Only when the last part arrives and is fitted, when the last hole is filled, can we move on to the next stage. And we do not know what will arrive last and how long it will take. Building creates delays, and they add up. For an individual part, no journey through the network will be like any other. This fact is simply a result of the complexity and interdependence of the network itself. Delay in the time taken by one process will add to the delays in processes further down stream. The resulting variability[3] in how long things take to do is a fundamental condition of any logistics system. Once we start dealing with the assembly of complex mechanical and electronic stuff, and the test and repair of components, we enter a world of probability distributions and queuing. It is like going for a haircut, having a car serviced or buying a stamp in the post office. We cannot rely on a precise schedule. How long it takes all depends on who else wants to do the same thing at the same time.

The crucial question is: how can we organise a logistic system to meet these demands effectively, when we know that the time taken to do things in any logistic system will always be variable?

This is important and bears emphasis. Logistics is made up of very simple processes, but these are arranged in a network of interdependencies that, when acting on the many different units of stuff that are needed to support each weapon, create a complex, busy, dynamic system full of *variability* (the first of our four key factors). To be successful, this system must respond to the demands caused by activity in the operations system; not just what is wanted now, but what may be wanted later; not just what is wanted by operations, but what is wanted by parts of the logistic system to complete work needed to continue productive throughput. This leads us to the second key factor.

How and when demands will emerge is a source of *uncertainty* for the logistics system. We do not know what will fail next, nor exactly when. This is the core problem for the partnership. We want continuous forward motion; to get this we seek certainty and speed, however, because of the very nature of logistics, we face uncertainty and delay. The crucial question is: how can we organise a logistic system to meet these demands effectively, when we know that the time taken to do things in any logistic system will always be variable?

(Continued on next page)

Most Significant Article Award

The Editorial Advisory Board selected "The Political Economy of Privatization for the American Military," written by Colonel R. Philip Deavel, USAF, as the most significant article in the Volume XXII, Number 2 issue of the *Air Force Journal of Logistics*.

Fightin' N' Stuff continued from previous page)

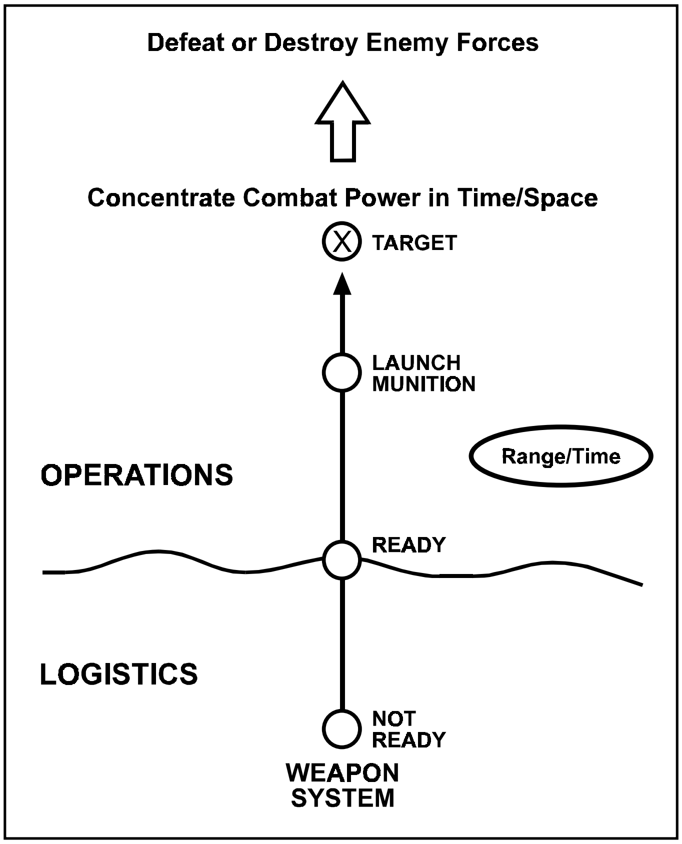

Figure 3. Mission

A good way to understand a process is to start with the end product and work backwards; in this context we need to stand at the front line of the world of operations and look to the rear (Figure 3). In simple terms, the final output from operations is an engagement, where a target is hit. To do this we have to concentrate combat power in time and space and this requires weapon systems loaded and fit to fight. This point of readiness is where operations and logistics touch. Notice that, in the world of operations, we are first concerned with range between the loaded weapon system and the target. This range translates into seconds, minutes or hours, depending on the weapon system. Whatever measure is used, the cycle of action—ready, aim, fire—is relatively quick. But an even more important factor is opportunity. The target is often moving and only visible or vulnerable for short periods of time. The cycle of action is not only quick; the opportunity to act is often fleeting. So readiness is crucial.

The activities that happen after—ready, aim, fire—we call recovery and regeneration. The weapon system is offline while we check serviceability, remove and replace failed parts and reload with fuel and munitions. Time taken for recovery and regeneration is influenced by the complexity of the tasks and the availability of good stuff to replace the bad (or to fill holes in weapon racks) and skilled people and the necessary tools and equipment to do the job. There are three types of output from this process. Firstly, a loaded weapon system: this goes back into the operations world. Secondly, information: this will include failure rates, time taken to replace components and perhaps new ways of doing work faster. We will also get information on how fast we are using our stocks, how many holes need to be filled. The third output is bad stuff that has been removed and replaced; this bad stuff will be input to the logistics system. The detail of what happens to the good stuff when it returns to the world of operations is outside the scope of this article. For our purposes of understanding what influences the task of concentration, we now need to follow the bad stuff back into the logistics black hole.

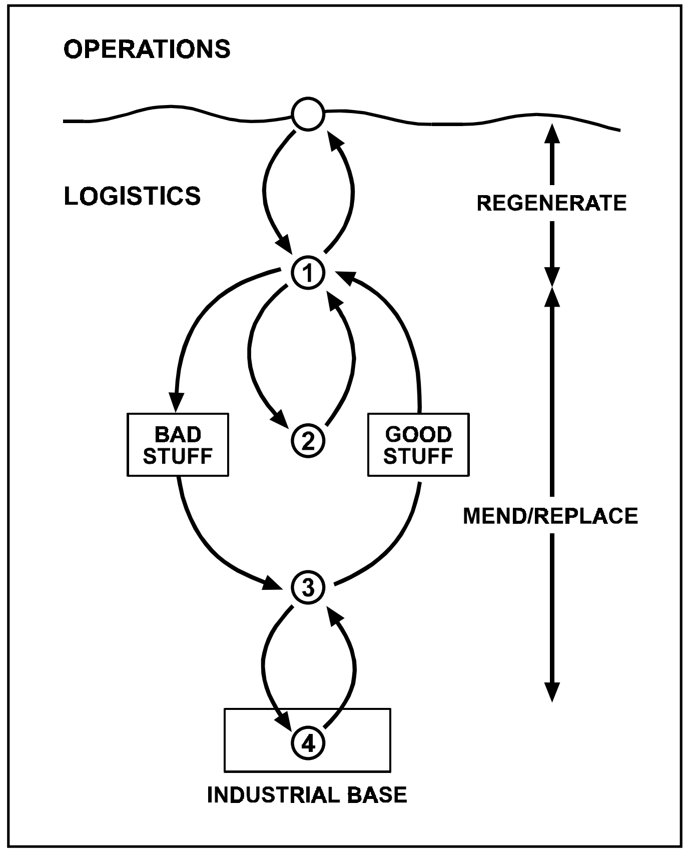

Figure 4. Interface and Echelons

In the logistics world we talk about echelons of support (Figure 4). As we move back from the interface with operations the complexity of work that can be done at an echelon increases. Typically, a first echelon task would be simply to remove and replace a black box in a system, or to rearm. At second echelon we might test functions and replace modules that can be simply plugged in or pulled out of the system. To address more complex maintenance and repair tasks, for example to do internal work on an aircraft power plant, we would expect to go back to a third echelon, where we have concentrated the skills, spares, tools and test facilities to gain economies of scale and a focus of expertise. Finally, for work such as complete rebuilds, or for small populations of very complex equipment, or processes involving exotic materials, we may move back to a fourth echelon, often to the commercial manufacturer. Where we put our echelons, and what capabilities we give them, largely determines the shortest possible time it could take to mend or replace things. How long work really takes is determined by the way we operate within this structure; in short, how effective we are as a team.

Earlier we saw that in operations we focus on opportunity and range, and we think in seconds, minutes or hours. In logistics

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we are first concerned with the time it takes to *mend* something, which will be at least hours and sometimes days. But, more crucially, when we think about moving stuff, we step into a world of distance and much slower speeds. Our units of time quickly move from hours to days to weeks as we move back through echelons one to four. We stop looking at the clock and start reading the calendar. Remember, it is not just the physical transportation that takes time; it is the preparation for movement, shipping delays and simple queuing for resources and facilities that really bite. And we are not moving just one package through the system; we are moving thousands, all competing for space and attention at every stage. To understand the nature of this movement, we need to take a look at pipelines and how they interact with the stuff that moves through them.

What do we mean by a pipeline? Often the first image that comes to mind is of very long tubes of metal crossing the tundra. Pipelines getting fuel from A to B. But any means of transporting stuff can be understood as a pipeline. We can think of a convoy of trucks on a road, men on bicycles struggling along jungle tracks in Vietnam, or a production line in a factory. Whatever their shape, size and components, when we describe them in systems terms all pipelines have three basic characteristics: capacity, length and flow rate. This means: how big and how heavy can each lump of stuff be? How many lumps of stuff can we have in the pipe at any one time? How far apart are the ends of the pipe? How fast can we push the lumps of stuff down the pipe? And most important of all, how long does it take between putting a specific lump of stuff in the pipe and getting it out at the other end? Also, for many pipelines, more capability often means less flexibility. Setting up a pipeline, or changing where we put the ends, are the classic problems of the fireman. The faster the flow of water and the wider the bore of the fire-hose, the more effort it takes to move. It takes more manpower, and it takes more time. And Heaven help the fireman if he has put the fire truck in the wrong street. He cannot stretch the hose, and he will have to empty it and roll it up before he can move the truck to where it is really needed.

It gets harder; in logistics we have to deal with many pipelines, of different capabilities, in a complicated and busy network. The most obvious problem in a network is how to have some control over the many flows that merge and diverge. If we are not careful we can overload smaller pipes by putting them downstream of bigger pipes. To keep the flow going we may have to speed up flow in a smaller pipe, or restrict flow in a bigger pipe that happens to be upstream. It is like plumbing. Coupling copper and plastic pipes of different sizes is not easy. In the transportation world one of the biggest challenges is getting this transfer right.

There is a golden rule: "just in time, not just in case." He who breaks this rule loses his gold.

Because of the uncertainty of demand, and the variability of the many processes connected by the logistics system network, the natural tendency of even a well designed system is for backlogs to build up and for flows to interfere with each other. Forward motion slows down and sometimes stops. In extreme cases the system can be paralysed. How can we deal with this natural tendency? To some extent the solution lies in good plumbing. We anticipate surges in flow and droughts in supply and design our system to be flexible. The most important technique is to position spares and spare capacity, at well chosen points in the system so that when there is any interruption in supply we can use the local buffer to produce what we need to fill the hole and keep forward motion going. We may think of buffers as header tanks, or reservoirs, producing steady pressure and uninterrupted flow. The goal is always to maximise throughput of the whole system. Buffers are essential but they take up space and cost money. The aim is to keep them to a minimum. Too much stuff in buffers is just as bad as too little. There is a golden rule: "just in time, not just in case." He who breaks this rule loses his gold.

There is one more pipeline characteristic we need to consider: invisibility. Despite attempts to track progress, most pipelines are opaque. We know what went in, but we often cannot see exactly where things are now. If a package is late we will know, but not that it is going to be late. Or even how late it may be. We take a bad thing and make it worse. We hide things when we put them together on pallets in batches to get economies of scale. This is the result of an inevitable trade-off. The aggregation of stuff for transportation gives us a cost benefit and moves more stuff faster. But it also makes the task of finding, reprioritising and redirecting individual items much harder. It reduces flexibility.

As a result of our analysis we can now propose the fundamentals of any logistic system as:

Variability of Process

Uncertainty of Demand

Capacity and Flexibility of the Network

Design and Management of Buffers

The first two are conditions, two of our four key factors that relate to the general nature of the partnership we are examining. The second two are the basic characteristics of any particular logistic system we may construct. As we step up out of the world of stuff and cross the interface with the world of operations we

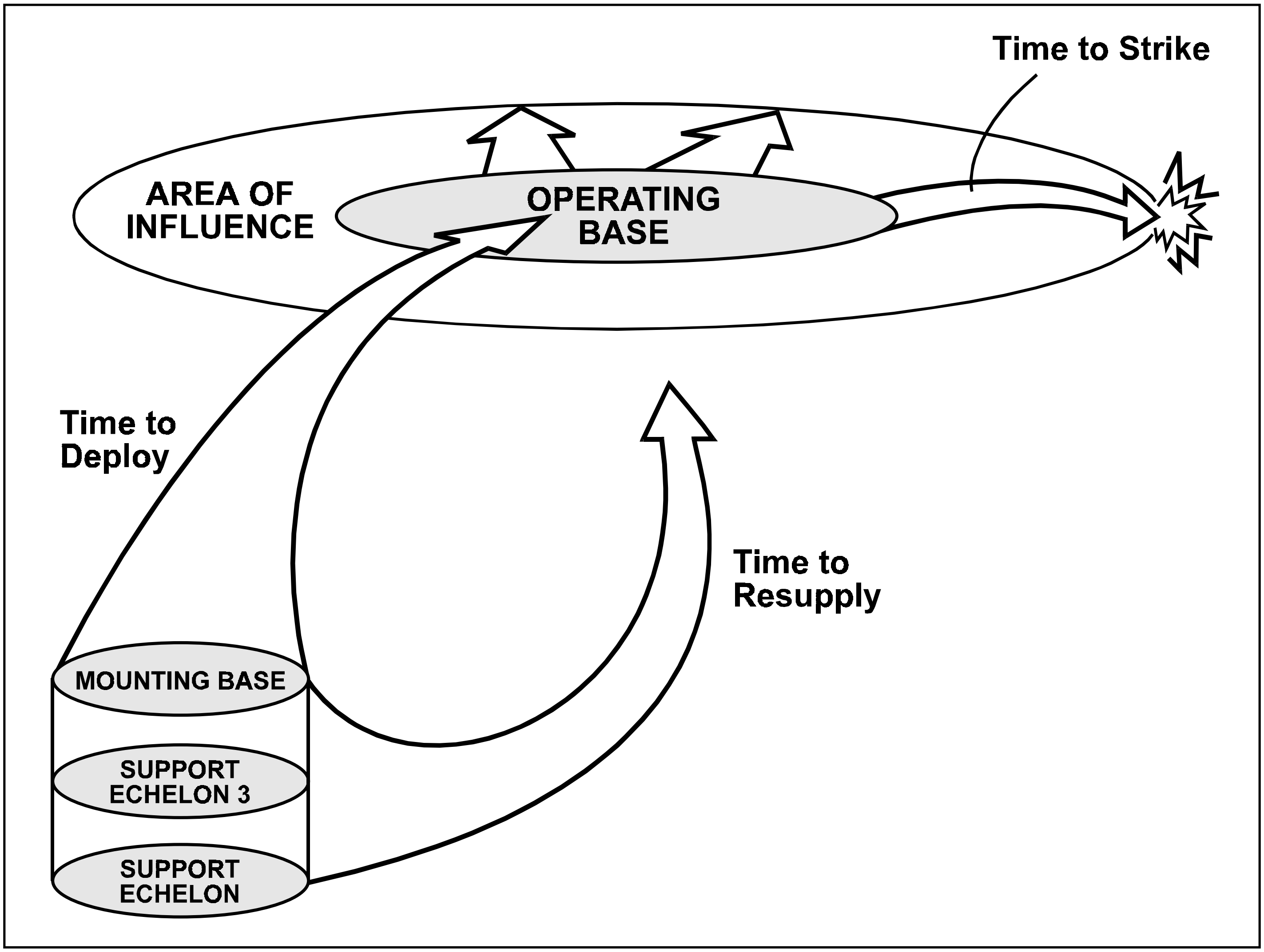

Figure 5. Power Projection

meet the third of our key factors. It is not a condition of either world. It is the fundamental quality of the partnership between operations and logistics—*synchronicity*. What does this strange term mean?

The goal of the operations system is to concentrate combat power in time and space. To make that possible, the logistics system has to concentrate stuff in time and space, and it has to be useful stuff. What is useful is defined directly by the needs of operations. Because they share the same stuff and feed each other with stuff and information, the processes in both systems need to be synchronised. But this is not easy to do; for two main reasons. Firstly, people working in operations and in logistics will tend to have very different time horizons. Operations is focused on range and fleeting opportunity; logistics is seeking continuous flows, often over long distances. This leads to different mind sets, a different sense of how fast things need to get done and how reactive to be. Secondly, each world has a different view of what constitutes a unit of work. The focus on stuff is different. This creates another tension between the systems that makes keeping in step hard. What is this different focus?

Logistics processes tend to batch repair work and to palletise stuff into shipments to get production and transportation economies, but this inevitably holds some things up. On the other hand, processes in direct support of operations focus on holes to be filled and therefore on the individual things that are needed to fill those holes. The urgency in the operations world to bring unserviceable weapon systems back online creates an imperative to get everything done immediately; from this point of view any delay is bad.

Our problem is to get and maintain synchronicity between two systems: each with a natural tendency to look at the world differently and march to different drummers. The solution lies in good system design and good planning processes and people who are comfortable with ambiguity and constant change. We have to remember the environment will always be unsteady. To succeed we need to be flexible enough to accommodate uncertainty of demand and variability of process. The truth is that logistic systems will never be easy to deal with: they are simply too complex, too dynamic and too big. We cannot ever fully control them; we can only prepare them and sustain them. Additionally, the partnership with operations is itself complex, dynamic and dependent on many actors. The resulting condition of *complexity* is the last of our four key factors. It is clear that, whatever else we do, to deal with the challenge of complexity we will always have to do a lot of thinking and organising before the shooting starts, if we are to hope to win.

Our problem is to get and maintain synchronicity between two systems: each with a natural tendency to look at the world differently and march to different drummers.

Part Two—The Dynamics of Fightin' n' Stuff

We have looked at the fundamental nature of the partnership. Now we need to examine how it works in practice by looking at the similarities and differences in the application of land, maritime and airpower. In the case of airpower we will look a little deeper. But first, we need to think about power projection in general terms (Figure 5).

From an operations point of view, the crucial determinants of effective power are the time to strike and the rate of striking. From a logistics point of view, the crucial determinants of effective support are: time to deploy, but in terms of useful packages of capability; and time to resupply, but in terms of useful amounts of useful stuff. Getting the bombers quickly into theatre is of little value if you have not got anything there for them to drop. So how does the nature of military power determine how operations and logistics work together?

For land forces, most of the support capability is relatively close to the operating base, and everyone is close to the battlefield. The echelon structure, with stocks, is massive, slow to deploy and relatively slow to move. We can imagine a force tethered by a large, unwieldy pipeline. It is true that in manoeuvre warfare forces may detach from the pipeline, but not far and not for long. In the Gulf we saw an operation lasting less than 100 hours resulting in an advance of perhaps 300 km. But this was at full stretch, after massive preparations and with no enemy strikes against our own logistics. The army structure moves as one; it flows in waves across the ground. Movement is punctuated by pauses to resupply and regenerate. When the forces are engaged, rate of consumption can be much faster than rate of resupply. Launch of the next offensive operation can be whenever the commander judges that enough forces are reloaded and in position to meet opportunity. Risk assessment is all. Opportunity may most often be due to enemy weakness and may be unpredictable in time and weight of effort needed. Small forces can have big effects if used suddenly, in the right place. Surprise and shock action pays off. This possibility puts a premium on mobility of logistics on the battlefield.

For naval forces, the operating base can always be moving. Because of this it has to be at the end of a long and flexible pipeline, that will of necessity be narrow and will be broken from time to time. Pipeline capacity is low and flow can be interrupted. For this reason a naval force needs more stocks and more *mending* capability on board the operating base. Like land forces, a navy has to take its buffers into the fight. Because of this, it is more critical to get things right before deployment; catching up is hard. Maximum power is fixed at the start of the operation when the fleet leaves its home port and diminishes rapidly once engagements occur.

What does the partnership look like in the case of airpower? The list of characteristics is well known, but what do the words mean? We can propose the following interpretation. Airpower measures by the clock rather than the calendar. Airpower can go anywhere, can attack scattered targets, attack deep targets and attack simultaneously over a wide area. Airpower can be very precise; and can be responsive: in the range of capabilities, in deployment and in the tempo of operations. But we must stress the conditional nature of all these capabilities, because to do all these things we have to get our bases in place, our capability to regenerate stuff online and our rounds, men and equipment in place to reload at the rate we need. And then keep it going. This, of course, is logistics.

So, for land-based air, there are similar challenges as in the cases of land and maritime forces, but also some unique opportunities to get sustained, flexible, combat power by carefully synchronising operations and logistics. The operating base is static, once deployed. But new bases can be activated relatively quickly and the forces can be redeployed between bases quickly and over long distances. As a result, air forces can build up power at the base to a schedule and adjust the schedule while build-up is in progress. More power can be brought to bear faster and in different places, far apart—what we may call *switchability*.

The capacity and flow-speed of supply pipelines can be increased given time and use of an air bridge which can redirect the flow of force multiplier stuff very quickly, stuff like the critical spare parts that keep weapons online. With an air bridge direct to the operating base the pipeline can be brought right up to the weapon systems. This capability is crucial for airpower because it relies completely on technically very complex and somewhat fragile systems operating far from support echelons. Despite steady improvement in reliability and maintainability of aircraft systems, the foreseeable future operations will continue to generate significant failure rates, resulting in a great deal of difficult test and repair work. With fast, reliable pipelines vulnerable regeneration capability can be kept further back from the threat. This means the number of support forces near the battle can be reduced, and this, in turn, reduces the requirement for force protection. If fewer personnel and less equipment are sent it does not take as long to deploy a force and it does not cost as much to keep them in place. We talk about reducing the mobility footprint. Fast reliable pipelines mean the flow around the repair loop can be speeded up and buffers of spares can be smaller. This reduces cost and releases funds for other purposes. For complex aircraft spares, moving them faster is usually much cheaper than buying more.

The reach of airpower means that commanders can often choose to put an operating base near or on a good transportation hub, readily maximising flow and so maximising combat power. Air forces are not constrained to line up with the enemy forces on a shared patch of ground and make the best of the infrastructure that happens to be there. Deployed air forces *en masse* are not limited by a finite magazine of weapons and the need to disengage and return to port for rearming. A word of caution: an important element of airpower flexibility comes from having a choice of weapons, but this choice can generate more uncertainty. For example, it introduces the question of what weapons to ship out, in what order, before the shooting starts. Here coordination between operations and logistics planning is critical. In general, air transport cannot move large quantities of heavy stuff, so we must to look far enough ahead to have time to send the bulk of weapons by sea. Nevertheless, well planned and adaptive resupply can match the consumption of stuff by air forces even under conditions of a sustained tempo of operations generated by a fast sortie cycle. If resupply is effective, air forces can reload and retask quickly and continuously. To achieve, this there must be good information and effective, integrated movement and repair processes.

We have seen that differences in the nature of the forces and their application naturally leads to differences in approach for the fundamental logistic processes of stocking, sustainment and regeneration. These differences in process determine how forces set up their structure, how they distribute stuff around the structure and in what quantities and the rules that must be followed to best manage their activities, to achieve success. So now we understand the nature and dynamics of the partnership: what is critical to success, what really matters most in doing fightin' n'stuff.

The goal for the partnership is to achieve concentration. To get the right stuff to the right place at the right time and to keep on doing it. This has to be achieved in the context of four conditions: variability, uncertainty, synchronicity and complexity.

Conclusions

The goal for the partnership is to achieve concentration. To get the right stuff to the right place at the right time and to keep on doing it. This has to be achieved in the context of four conditions: *variability*, *uncertainty*, *synchronicity* and *complexity*. To deal with these key factors we have to have two things, the right attitude and the right fitness: doctrine and capability. The right attitude helps us identify what must be done; fitness provides the energy and flexibility to do it. The right attitude is to think first and most about just five things.

1. The operations/logistics partnership is a target for our enemy—protect it.

We must try always to think of an enemy looking for the decisive points in the partnership. What we want to make strong, they will try to weaken. Where we want agility, they will want to paralyse us. What we can do to our enemy, we can do to ourselves by lack of attention. So all concerned with operations and logistics must protect and care for the partnership and the things it needs for success. This includes stuff and information and people. Also, we must not forget, the corollary is just as important: the operations/logistics partnership of the enemy is a target for us, we must attack it.

> The layman tends to associate air superiority with destruction of enemy aircraft . . . it is not the only approach. A potentially vulnerable sequence of events (the aircraft chain) must take place before an aircraft fires a missile or drops a bomb . . . it is possible to eliminate an air force by successful attacks on any point in this chain.[4]
>
> —Colonel John Warden III, USAF

2. Think about the physics.

Stuff is heavy and it fills space. Anything we want to do needs to take account of the weight that will have to be moved, over what distance, with what effort. Usually this all comes down to time, a delay between the idea and the act. If we think about the physics we can know the earliest time we can finish any task and we can separate the possible from the impossible. It is crucial to determine the scope of the physical logistics task early in any planning process. Planners must know how long things take and why they take that long.

3. Think about what needs to be done when—and tell everybody.

Once we have given instructions and the stuff is in the pipeline it will fill that space until it emerges at the other end. The goal is to make sure that the stuff coming out of the pipe is exactly what is needed at that point in the operation. If it is not then we have lost an opportunity—useless stuff is doubly useless. Useless in itself and wasting space and effort and time. Moving useless stuff delays operations. Even in a shooting war extra missiles are a luxury if there are already enough for the next three days, but aircraft are grounded for lack of engines. In setting priorities it is important to think about what might have to be done, even if it is not part of the current plan. It might be tempting to insist on maximum numbers of all alternative weapons choices being shipped to a base, but if there is no thought given to the sequence of arrival of the right mix, the enthusiastic but undisciplined outloading of weapons might put back the earliest time action can be taken. For example, changes to rules of engagement or other operational factors, such as prevailing weather conditions, may introduce limits on which weapons we can use legally or effectively. Also, priority of order of arrival will change with conditions and with the nature of the force deploying. For example, the political need to show a presence quickly may lead a commander to take the risk of using the first air transport sorties to get aircraft turn-round crews and weapons into theatre before deploying all the force protection elements.

4. Think about defining useful packages of stuff.

Stuff is only useful when all the pieces to complete the jigsaw are assembled. Until the last piece arrives there is nothing but something complicated with a hole in it. It is vital to know exactly what is needed to make a useful contribution to the operational goals and to manage effort to complete unfinished jigsaws, not simply to start more. Useful stuff often has a *sell-by* date. If it arrives too late it has no value and the effort expended has been wasted. The sell-by date must be clear to everyone who is helping build the jigsaw. And it is important to work on the right jigsaw first. In any operation there is a need to relate stuff in the pipelines to joint operational goals, not to single service or single unit priorities. It is no good having all the tanks serviceable if the force cannot get enough aircraft armed and ready to provide air cover; or ensuring that the bomber wing gets priority at the expense of its supporting aircraft.

5. Think about what has already been started.

The length of a pipeline is measured in time not distance. There will always be a lag in the system and it is important to remember what has already been set up to happen later. Constantly changing instructions can waste a lot of energy just moving stuff around to no real purpose. Poorly conceived interventions driven by narrow understanding of local and transitory pain can generate instability and failure in the system.

So, there are five things to think about. But thinking is not enough. We have got to be smart and fit to win. It is important to conclude with some thoughts on the fitness we must seek to guarantee a robust partnership of operations and logistics.

We must not become so focused on what we have planned for that we fail to recognise and respond to what is really happening.

We need systems that can cope with damage, disruption and confusion. Remember, we expect variability in performance, just by the nature of the logistic processes. We need simple rules, simple procedures and a clear view of the mission. People must be in no doubt of what they should be trying to achieve. This might be compared with the notion of *mission command*. We must not build systems that are rigid and too dependent on fixed infrastructure; this mistake is usually the result of seeking local efficiencies without considering the impact on overall system effectiveness. The partnership has to be resilient. We need systems that can respond quickly and effectively to change. Remember, we expect uncertainty in demand just by the nature of the activity we are supporting. We need to be ready and able to redirect and accelerate, and we must be open to learning as we go and to exploiting new knowledge immediately. We must not become so focused on what we have planned for that we fail to recognise and respond to what is really happening. Both partner systems have to be adaptive.

We need a partnership that concentrates effort on meeting operational objectives so every action adds the maximum value to combat power. As much as we can, we must link what we do in the logistics system directly to the contribution in combat readiness. We must not work to measures of output at intermediate sections of the pipeline; we must measure all performance in terms of the outcome at the business end of the pipe. Logistics has to be focused on operational outcomes.

What we always face are trade-offs, in time, investment and operational opportunity. One of the purposes of deliberate

Knowing what the critical success measures are comes from good analysis and design—from asking the right questions, from thinking clearly about the system we work.

planning, and the exercising of systems for real, is to highlight these trade-offs, to understand their interdependencies and to learn how to get the best result even when we do not have all the facts. A robust partnership will beat a tidy plan, every time. The focus of trade-offs at the operational level is the commander. His planning and execution must be centred all the time on the need to synchronise operations and logistics. Making trade-offs is unavoidable; variability and uncertainty see to that. But making better trade-offs, faster than the enemy, is how we win. Knowing what we are doing helps. And doing as few stupid things as possible and as many clever things as we can is important. We need knowledge on what is happening, why and how it will change things. Information on the performance of critical success measures in the process is crucial to gaining these insights. Knowing what the critical success measures are comes from good analysis and design—from asking the right questions, from thinking clearly about the system we work.

Experience teaches that most often things go wrong because of poor understanding and poorer communication, because of lack of clear focus on essentials, on what really matters. Too often we work at doing things right, not on doing the right things. We measure efficiency rather than effectiveness. Thinking about the nature of things is hard. But it is what we must do if we are to truly understand and be effective.[5]

> Gentlemen, the officer who doesn't know his communications and supply, as well as his tactics, is totally useless.
>
> —Lieutenant General George S. Patton, USA

Notes

1. Widely used misquote of: "I always make it a rule to get there first with the most men."
2. Foster, D. J., "A New Look at Wholesale Logistics," *Air Force Journal of Logistics*, Volume 19, No. 4, Fall 1995.
3. Womack, J. P., Jones, D. T., and D. Roos, *The Machine that Changed the World*, New York: 1990. Goldratt, E. M., *Theory of Constraints*, New York: 1990.
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5. Handy, C., *Understanding Organisations*, Oxford: 1993.

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International Armaments Cooperation: Can It Fulfill Its Promise?

First Lieutenant Paul L. Hartman, USAF
Craig M. Brandt, PhD

Introduction

For a half century following World War II, the US and its allies spent a great deal of time and money preparing for a possible war with the Soviet Union. In the beginning of the final decade of the 20th Century, this focus suddenly changed. With the whole world watching, the colossal Soviet Empire fragmented and fell, putting an end to the Cold War and, removing the imminent threat of communist expansion.

Yet threats to international security have not totally disappeared. Rising civil unrest around the world, the proliferation of advanced weapons, including weapons of mass destruction by rogue nations, and environmental and resource degradation due to demographic pressures continue to cause anxieties around the globe. Meeting the challenges of such threats will be especially challenging in a world that is confronted with rising weapons costs and political pressures to reduce defense spending.

Under these circumstances one possible strategy is international armaments cooperation, where the DoD could realize political, economic and technological benefits such as improved international political relationships, shared research and development (R&D) costs and access to foreign technologies. Under circumstances

> . . . when no one nation possesses all the best technologies, when no one nation has unlimited resources, and when nations will be coalition partners, the case for international armaments cooperation is compelling.[1]

Unlike Europe, the US does not incorporate armaments cooperation into its defense strategy, but the notion of international armaments cooperation programs is an appealing method of developing and acquiring weapon systems in an era of reduced defense spending.

This article describes the current state of arms cooperation and discusses issues in American international cooperative development practices and policies in the 1990s. It highlights two models for developing weapons systems in a cooperative environment: the Medium Extended Air Defense System (MEADS) and the Joint Strike Fighter (JSF). Although both programs demonstrate cooperation, the MEADS program was envisioned as a cooperative project, whereas the JSF program started as an American endeavor and later phased in cooperative partners. These programs typify the current approaches to international cooperation in developing US defense systems.

Today's Vision for Cooperation

American defense leaders have increasingly championed arms cooperation over the past few years. Unlike Europe, the US does not incorporate armaments cooperation into its defense strategy, but the notion of international armaments cooperation programs is an appealing method of developing and acquiring weapon systems in an era of reduced defense spending. In 1993, then Secretary of Defense William Perry established the Armaments Cooperation Steering Committee to "lead a renaissance in armaments cooperation" and to oversee the DoD's armaments cooperation activities. These specific activities included ensuring its priority status among DoD operations, compliance with the US national security policy and coherence in all phases of cooperation, from R&D to production, procurement, licensing and sales. This bold step in arms cooperation favors the possibility of increased cooperation in the future.

Dr. Paul G. Kaminski, Under Secretary of Defense for Acquisition and Technology, pushed international cooperation to the forefront of defense acquisition efforts. In a January 1995 speech to the Industrial College for the Armed Forces, Dr. Kaminski noted that US allies will be important partners in mitigating regional conflicts.[2] In a subsequent speech at the Center for Strategic and International Studies, he linked cooperation with coalition building, referring to an increasing reliance on cooperation to meet US and allied security requirements as a *renaissance in cooperation*. He mentioned the mutual interest in exploiting cooperative partnerships and further emphasized three reasons why he believed the United States should seek armaments cooperation opportunities.

The first reason is political: these programs help strengthen the connective tissue—the military and industrial relationships—that bind our nations in a strong security relationship.

The second reason is military: there is an increased likelihood of operation in a coalition environment where we need to deploy forces with interoperable equipment and rationalized logistics.

And the third is economic: our defense budgets and those of our allies are shrinking. What we cannot afford individually may be affordable with a common effort.[3]

While rededicating the US to building a more acceptable environment for arms cooperation in the future, Dr. Kaminski's message was significant in that it admitted to a poor history of international cooperation. The message targeted some of the failed or unfinished cooperative projects, such as the Mark XV Identification Friend or Foe (IFF) air-to-air identification system and the Advanced Short-Range Air-to-Air Missile (ASRAAM). After touching upon the challenging and complex reality of international armaments cooperation, he completed his talk on a note of hope and vision for successful cooperation in the future.

Although US defense leaders have espoused such visions for the last 20 years, progress has been slow. For this reason, the Office of the Under Secretary of Defense for Acquisition and Technology requested a Defense Science Board Task Force convene to investigate international armaments cooperation issues. In August 1996, the Chairman of the Defense Science Board, Craig Fields, reported,

> We believe that the recommendations of this Task Force are an important change in the way we go about doing international cooperative efforts and, if implemented, would significantly raise the probability of success on future selected programs—as well as increase the number of such efforts.[4]

After listing the benefits of armaments cooperation (reduced R&D costs, access to foreign technologies, interoperability, etc.) the task force concluded the US has thus far shown very limited interest in cooperative endeavors.

On 28 March 1997, Secretary of Defense William Cohen signed a powerful policy memorandum concerning DoD international armaments cooperation. The memorandum directed that international armaments cooperation be used to the maximum extent feasible and suggested, as a minimum, that a greater emphasis be placed on "deployment and support of standardized, or at least interoperable, equipment with our potential coalition partners" to "leverage . . . US resources through cost sharing and economies of scale."[5] It named the Under Secretary of Defense for Acquisition and Technology as the office of primary responsibility for all international armaments cooperative actions and issues and directed its coordination with any affected DoD components. In addition, this office was instructed to identify opportunities for cooperation. The policy was effective immediately.

Additionally, the US has taken steps to remedy protectionism in the defense marketplace with the McCain Amendment to the 1997 Defense Authorization Act. The amendment allowed the DoD to relax some *Buy American* provisions for those countries which have opened their markets to US companies. This measure sends a positive political signal to those countries desiring to sell defense equipment to the US.

Benefits of Cooperation

The real benefits of cooperation can be expressed simply. For collaborative development, the central issue is to reduce national development costs and risks through bilateral or multilateral consortia of nations or manufacturers, thus avoiding duplication of R&D costs which are reaching astonishing heights. Traditionally, nations have invested in weapon systems individually. Even among partners in an alliance such as NATO, each nation has typically approached weapon acquisition alone, even if the desired system addressed mission needs or operational requirements that are shared by potential allies. Consequently, duplication of research efforts, even among logical partners, was rampant.

The costs of duplicated research and development could be readily seen in the fighter aircraft acquisitions of the late 1980s and early 1990s. The US was developing the F-22, France the Rafale, Italy the AMX, a European consortium the Eurofighter and Sweden the Gripen. Thus, among ourselves and our European allies, five fighters were being designed, all of which shared some identical design problems and all of which carried expensive price tags. Similar examples can be found in missiles and tactical vehicles.

Cooperation can ensure a pooling of technological resources to develop a weapon which will meet the needs of all participants in the project. In past years, the US could confidently assume that its technology was without equal, and dealings with other countries could always be conducted from a position of advantage. Today, however, globalization of defense technology has taken place, and the US no longer has a monopoly on major innovations. Thus, access to advanced technology can be gained without the necessity of independent research and duplicative investment. Money saved in this fashion permits advancement in other areas that may have previously been deprived of funding.

To achieve maximum benefits, cooperation must start at the very beginning of the research and development phase. Most of the savings that will be realized by developing a major weapon system cooperatively come during the R&D and concept exploration phases of a program. Otherwise, the program becomes, at best, simply another example of coproduction.

Major benefits of industrial teaming, then, include drawing on the strengths of each partner to produce better systems, reducing R&D costs and eliminating duplication to create a more economical and better coordinated defense posture—thus providing economic benefits to all partners.

. . . the reason for intermittent US participation in arms collaboration projects is because the US does not view cooperation as instrumental to building an effective defense capability.

Obstacles to Cooperation

The Aerospace Research Center in Washington, DC, suggests the reason for intermittent US participation in arms collaboration projects is because the US does not view cooperation as instrumental to building an effective defense capability. Further, it charges that

> . . . lack of emphasis on defense trade, poor coordination of cooperative efforts, little support among the military services and weak political support have worked against the success of international defense cooperative programs.[6]

The Politics of Participation

It is difficult to determine each nation's definition of *equitable* as they enter into cooperative arrangements. Among potential cooperative partners, one issue that must be addressed is harmonizing the individual agendas of each country. Some countries will enter into a cooperative effort for jobs created in the work-share process and not necessarily for the technology. Others want to drive the program to a point technologically that may not make the system as effective as potentially possible. Requirements commonality is the goal; if agreement cannot be reached on all partners' individual needs—whether too flexible or too specific—the program may not succeed. Once the program is past initial requirements identification, which is perhaps the most difficult stage, the cooperative program is well on its way, so there must be a political consensus up front that establishes what the partners want the program to do.

Concerning the question of the extent of international participation, there are those who feel the degree of involvement should be directly proportional to their level of resource infusion.[7] To measure this, it is essential to come up with a mathematical formula to cost out each phase of the program as if the US was engaging in it alone. This way, one can use the partnering nation's resource contribution as a percentage of input to calculate the level of work-share for that country. Advocates note this works better at the end of the program because in the early stages of development it is difficult to place a monetary value on qualitative areas such as the initial requirements generation process. However, if international shares are not computed until late in the program, any real advantages of cooperative R&D are lost.

A common view by supporters of international cooperative programs suggests it costs more and it takes longer up-front to participate in an international cooperative program.[8] The consensus is a cooperative program will cost approximately 120 percent of what the US would spend to build the same system. However, while the overall costs of a cooperative program may be higher, the shared costs for each participating country are lower.[9] Each partnering nation thus realizes the benefit of a collaboration.

Logistics Support

Current American initiatives in logistics support may have an impact on many international programs. As the DoD continues its efforts to reduce defense spending by outsourcing support activities including currently organic maintenance, the use of contractor logistics support and the privatization of US depots, there may well be an adverse impact on cooperative programs under consideration. If there is to be shared logistics support, some means of accommodating international partners must be found. Also, US government officials have a responsibility to the American taxpayer. Most Americans want their tax dollars spent in the US—which is the same desire that all cooperative partners have with regard to their own domestic situations. They do not want to see their tax dollars go to overseas companies when US depots are under utilized and are being considered for closure.

Program Management

While armaments cooperation from the American viewpoint always envisions the international expansion of an American weapons program, there is no reason why a foreign program could not have US participation. Nonetheless, sentiment is heavily weighted against the loss of control that would result if that were the case. Officials overwhelmingly pointed to one program management challenge that could appear in a major weapon system acquisition where the program director is not from the US. This concern is the ability to create an organization that adequately supports US-specific requirements. Other issues mentioned include the director's ability to support an international Integrated Product Team structure, to integrate budgetary cycles of different nations and to overcome communication barriers, such as language and computer compatibility.

As the DoD continues its efforts to reduce defense spending by outsourcing support activities . . . there may well be an adverse impact on cooperative programs under consideration.

The Air Force's acquisition system may pose special problems. Integrated Weapon System Management (IWSM) may be made more difficult because the span of direct US control during the acquisition process is significantly affected when the program is directed through an international steering committee. In addition, many express concern over the ability of the program managers to communicate with regard to issues, ranging from planning to follow-on support of a weapon system. Thus, supporters of international armaments cooperation at the senior Air Force level questioned the ability to effectively implement the *cradle-to-grave* philosophy of IWSM for a large-scale cooperative project, such as a major weapon system acquisition effort.[10]

Models of International Cooperation

There are currently two distinct models which may be considered as future baseline models for guiding armaments cooperation. These include the MEADS, a model of trans-Atlantic teaming; and the JSF, a *common family of aircraft* approach to joint and international cooperative development.

The Medium Extended Air Defense System

MEADS is a mobile surface-to-air missile system that is capable of providing 360 degrees of defense protection for troops and other assets against short-range ballistic missiles and cruise missiles.[11]

MEADS is a cooperative partnership among the US, Germany and Italy with a cost share of 60, 25 and 15 percent respectively for the program definition and validation phase. France was initially involved in the project but withdrew because of a lack of funds and a distrust of the American commitment to the program. This partnership utilizes the concept of trans-Atlantic teaming, an international arrangement of primary contractors and subcontractors that allows competition on an international level. The purpose of employing trans-Atlantic teaming arrangements is to ensure the benefits of international competition are present in the procurement effort, while at the same time maintaining strong political and military ties with European allies.

There are two trans-Atlantic teams for the MEADS program which are scheduled to complete the program definition phase in late 1998, one led by Raytheon and the other by Lockheed Martin. Each team has a 50-50 arrangement with the European consortium named Euromeads. This European consortium is comprised of a group of well-known defense companies in Europe, including Italy's Alenia Aerospazio, Daimler-Benz's LFK subsidiary and Siemens, both of Germany All members of the European consortium have equal shares in the overall development of the project. At the end of the program definition phase, one of the teams will be selected to take the program into the design and development phase.[12]

The Joint Strike Fighter

The JSF is a multi-role strike fighter aircraft expected to replace the Air Force's multi-purpose F-16 and A-10, the Navy's long-range A-6 attack plane and possibly its F-14 fighter and the Marine Corps' AV-8B jumpjet. In the international arms market, the short-take-off-and-vertical-landing (STOVL) version of the JSF is currently expected to replace the United Kingdom's Royal Navy Sea Harrier aircraft.

From its inception, the JSF program was structured to be a flagship for acquisition reform. In addition, the JSF program has been recognized as a potential model for international cooperative development programs. Unlike its predecessors, the JSF program has involved international partners in the early stages of the operational requirements identification process. The program uses the *common family of aircraft* approach to procurement. The JSF program includes three different aircraft designs with several key components in common, including engines, avionics and structural components. This satisfies the strike warfare requirements of the Navy, Air Force, Marine Corps and international partners. All three aircraft variants will be produced on the same production lines using flexible manufacturing technology.

International cooperation in the JSF program is based on four program-unique levels of participation determined by the amount of money contributed by a government partner:

- The highest level of involvement by US allies cooperating in the JSF program is known as a *Collaborative Development Partner*, or Full Partner. The United Kingdom (UK) signed a Memorandum of Understanding (MOU) in December 1995 and currently is the only nation participating at this level. The UK has committed to contributing $200M to the concept demonstration phase, with the expectation, but no guarantee, that British industry will gain a 10 percent stake in what is anticipated to be a $10B development and production program.[13] As Collaborative Partners, the UK and US have equal influence over the development of the STOVL version of the JSF. The objective of the both partners is to harmonize their unique operational requirements in order to field a superior weapon system to replace their aging Harrier fleets.
- An *Associate Partner* in the JSF program again works under an MOU but has only limited participation and involvement in the decisions where requirements, technology or other core processes are concerned. This relationship gives these countries the opportunity, depending upon data disclosure access, to harmonize future operational requirements by using their threat data in JSF simulation models. In addition, they have input, but not direct influence, regarding the requirements evolution of the conventional-take-off-and-landing version of the JSF. Through this exposure, Associate Partner countries are able to determine if the JSF is a valid replacement for their aging F-16 fleets. Memoranda of Agreements (MOA) have been negotiated with Denmark, Norway and the Netherlands. Collectively, these nations have contributed $32M to the program.[14]
- The third level of involvement in the JSF program is the *Informed Partner*. As the name suggests, this level of participation allows the country to be informed or have access to JSF trade studies in order to evaluate the weapon system as a possible replacement for their current aircraft. This level does not afford the participant any level of influence in the program's processes. Canada has paid a $10M fee as an Informed Partner. Italy and Australia are currently involved in technical discussions with the JSF project office.
- The last level of participation allows members of foreign industry to engage US industry in future partnerships by subcontracting with prime US contractors in subsequent phases of the program. The UK is strongly participating at the industrial level. British Aerospace (BAe), originally affiliated with McDonnell Douglas before the latter was eliminated from the JSF competition, has joined the Lockheed team with a 12 percent share of the development and production rights if Lockheed prevails.[15] In addition Rolls-Royce/Allison is allied with General Electric in the engine competition. Other British firms involved in this endeavor include Dowty Aerospace, Meesier-Dowty, Martin Baker and Lucas Aerospace.[16]

Are These Models of Success?

Both MEADS and JSF represent different models of international cooperation. While each has its supporters, both deserve closer examination to see if they truly fulfill the objectives of a codevelopment effort.

For the Europeans, MEADS represents an ideal program since they have a significant voice in the program and guaranteed industrial participation. However, MEADS has demonstrated many of the same weaknesses as many of the failed cooperative programs of the late 1980s and early 1990s.

While the European partners are firmly committed to the program estimated to result ultimately in $40B worth of contracts over 15 years, the US is unwilling to provide for program continuation in its budget. Neither the Ballistic Missile Defense Organization nor the US Army included the program in the 1999 long-term funding proposal. Likewise, it was not included in the DoD's Program Budget Decision 224 of November 1997 nor in the 1999-2004 Program Objectives Memorandum (POM). Consequently, Congress assumed the DoD had no interest in supporting the program and cut MEADS funding from the 1999 Defense Authorization Bill. The Europeans hoped the money could be restored in a supplemental bill and that MEADS would be included in the 2001-2006 POM.[17]

These conditions are reminiscent of many of the Nunn Amendment programs after 1986 where the US had several similar competing programs and was never willing to commit wholeheartedly to the international one. Unilateral American withdrawal destroyed the 155mm Autonomous Precision Guided Munition program, the Modular Standoff Weapon, terminal guidance warheads for the Multiple Launch Rocket System and the NATO identification system. European authorities point out the failure to proceed with MEADS will probably kill all interest in trans-Atlantic efforts.

The JSF program, while billed as an international program, fulfills only some of the promise of a normal codevelopment program. Only those countries that opt to join as Collaborative Development Partners will participate in any real sense in the development of the aircraft. This level of participation requires a commitment on the part of both the government as well as major industrial enterprises within the country to devote substantial resources to the program. It is only a Full Partner, too, that will reap the benefits of a traditional codevelopment program, that is, those deriving from having industrial involvement in the R&D associated with the new technologies. Only at this level will a foreign government be able to influence the design to satisfy its own requirements. Thus, in the JSF program, only the UK truly represents a Collaborative Developmental Partner.

As Associate Partners or Informed Partners, governments are permitted access to some of the processes of aircraft development, but their influence over the requirements is either limited or non-existent. There is no guarantee of data disclosure, which is the hallmark of a true codevelopment program. Historically, failures in this area are often the downfall of codevelopment attempts, since sharing of technical data is one of the major techniques of reducing R&D expenditures—the driving rationale behind codevelopment in the first place. In the JSF program, the international partners will gain a substantial amount of information which will permit them to analyze the new plane as a replacement for current fleets, but they do not seem to take advantage of any industrial benefits or technology inherent in a traditional cooperative program.

At the lowest level of participation—industrial relationships as subcontractors—there is not necessarily any guarantee of developmental work at all. Given the state of the globalization of the aerospace industry, foreign industrial participation in the production phase is to be expected, whether the program has created such a defined category or not. This would certainly be true if foreign buyers of the aircraft demanded any sort of offsets as a condition of purchase.

These two programs, then, are celebrated by their supporters as accomplishments in international cooperative development. Both, however, are imperfect models for the future. In the case of MEADS, as in many Nunn Amendment programs of earlier years, European interest in the weapons system is high, and the partners are willing to invest heavily in the program. On the other hand, the US apparently has alternative programs to accomplish the same mission and has been unwilling to commit to long-term funding for the program. Another unilateral pullout by the US will send a very strong signal that we are not really interested in cooperative programs.[18]

Of the various levels of international participation in the JSF program, only the highest level provides any real collaborative development with the possibility of influencing the outcome of the program. Participants at the other levels do not achieve the benefits associated with cooperation, but seemingly aim at receiving enough information to be informed purchasers of the final version of the aircraft. The resources devoted to these levels of participation are minimal and result in virtually no influence in program development, nor meaningful technology transfer or industrial work-share.

The Cooperative Road Ahead

In an era of declining defense budgets, international arms cooperation is a good business practice. Both the US and its allies will enjoy greater economies of scale, minimized risks, access to foreign technologies and *best-value-for-the-money* products offered by collaboration. With NATO expansion underway and defense procurement down 75 percent since Fiscal Year 1985, there appears to be an even greater urgency to team with allies and exploit the benefits of armaments cooperation.

The consensus among current managers is that American systems must have a high degree of operational interface with existing and future allied defense systems if US military strategies are to be effectively implemented.

The consensus among current managers is that American systems must have a high degree of operational interface with existing and future allied defense systems if US military strategies are to be effectively implemented. The use of international cooperative programs to develop future defense systems, especially those developed with countries expected to become members of coalition forces, is important. It is significant not only in terms of the interoperability and commonality of the systems, but also in terms of minimizing the logistics footprint necessary to support these coalition forces in forward areas.

However, lessons of the past should be fully understood by all cooperative partners before agreeing to any cooperative project. Defense authorities alike, from all NATO countries, agree that arms cooperation is an effective solution to weapons development and procurement challenges, but they also recognize that cooperation does not work in every case. It is up to the participating countries to overcome historical barriers to successful arms cooperation by following newer models for such endeavors. Every effort must be made by participating countries to act as an alliance from the early stages of a project through its completion. The objective, therefore, is not to achieve international arms cooperation; rather it is to strengthen a

(Continued on top of page 42)

Expert Provisioner: The Development and Implementation of a Knowledge-Based Decision Support Tool for Royal Air Force Reprovisioning

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Introduction and Overview

The Royal Air Force (RAF) operates a single echelon, centrally controlled inventory system to manage an inventory of approximately 855,000 line items; nearly 680,000 of which are consumables. Generally speaking, consumable items are those which are either consumed in use or are otherwise not economically reparable. Each of the consumable items in the RAF inventory is subject to reprovisioning as shelf-stock is consumed. During reprovisioning, Range Mangers (RMs) must take order quantity decisions that will minimise the risk of future stock-outs while also minimising investment. Successful consumable item reprovisioning requires a staff of RMs with a great deal of specific knowledge about item characteristics and customer requirements, coupled with a high level of expertise in reprovisioning procedures. Although the RAF Supply Central Computer System (SCCS) calculates proposed reprovisioning Order Quantities (OQs), Range Managers must review item provisioning parameters, demand trends and financial considerations before initiating procurement. Following the review, RMs have the difficult task of either accepting, based on their expert knowledge and judgement, or adjusting the proposed OQs.

Although expert knowledge is crucial to the reprovisioning Order Quantity decision, many Range Managers lack the years of experience needed to acquire the requisite level.

Although expert knowledge is crucial to the reprovisioning OQ decision, many Range Managers lack the years of experience needed to acquire the requisite level. This situation has arisen because of two primary factors. First, the RAF, like most other military organisations around the world, has experienced a significant manpower draw down during recent years, resulting in the redundancy of many of the RAF's most experienced Range Managers. Second, since Range Managers are relatively low-grade Ministry of Defence (MOD) employees, many of the best RMs seek and obtain early opportunities for promotion in other logistics support positions.

To address the problem, a knowledge-based system (KBS) called Expert Provisioner (EP) was developed to assist inexperienced RMs with the reprovisioning task. The literature is replete with definitions of a knowledge-based system. In the context of our work, we define a KBS to be "a computerised collection of simple rules that when used together, will emulate the decision process of an expert performing a complex task." The remainder of this article further details the problem being addressed, provides additional explanation as to why a KBS solution was pursued, overviews the functionality of the Expert Provisioner program, provides preliminary results and discusses the current status of the EP production system development effort.

The RAF reprovisioning system is a classical inventory process where a reorder point and order quantity is calculated for each item based upon item parameters and expected demand over the item lead (resupply) time.

RAF Consumable Item Reprovisioning

A brief description of the RAF consumable item reprovisioning process is necessary to frame our subsequent discussion of the Expert Provisioner KBS system. The RAF reprovisioning system is a classical inventory process where a *reorder* point and order quantity is calculated for each item based upon item parameters and expected demand over the item lead (resupply) time. When the serviceable balance for an item breaches the computed reorder point, a document called *Request for Requisition (R001)* is generated by the central computer system. The R001 document contains a proposed order quantity (OQ) for reprovisioning. The proposed OQ is calculated by the central system using an Economic Order Quantity (EOQ) methodology.

The hard copy R001 document is forwarded to the RM responsible for the item for reprovisioning action. The number of fields (approximately 150) varies depending upon the number of existing requisition and contract records and the number of system-generated remarks.

Upon receipt of an R001, the Range Manager conducts a visual review of the item provisioning parameters to ensure accuracy. This task requires a great deal of expert knowledge. First, RMs must understand the meaning of the myriad of acronyms on the R001 document. Next, they must understand the impact of each of the parameters upon the OQ decision. In addition, they must be experienced enough to detect *suspect* parameter values that warrant further investigation. If the RM has all those skills, then he or she must be able to determine how the alteration of one or more of the item provisioning parameters will affect the item reprovisioning order quantity.

Arguably, determining the *right* reprovisioning OQ is a difficult task for even very experienced RMs. What makes the task even more difficult is that many factors that affect the order quantity are not provided on the R001. In addition to item parameter accuracy, RMs must often consider factors such as price-break opportunities, shifting demand patterns, customer ordering errors, budget constraints and varying order procedures in deciding upon the *right* reprovisioning order quantity. All these factors combined, coupled with the general low experience level among RMs, clearly makes the reprovisioning task very difficult.

Why a KBS Approach?

The literature indicates that knowledge-based systems are best suited for situations where expert knowledge is largely heuristic and uncertain.[1] This is clearly the situation often facing the Range Manager. In cases where KBS solutions are appropriate, the literature promises an impressive list of potential benefits.[2] With respect to our application, the following benefits are highly desirable:

Permanent, Online Source of Expertise

Range management is a relatively low grade, entry level position within the MOD with little opportunity for advancement. Thus, as mentioned earlier, after some experience is gained, RMs often seek transfer to other departments where they may gain broader experience to more quickly qualify for promotion opportunities. Since a KBS rule base effectively captures expert knowledge, the effect of this continuous loss of human expertise will be mitigated.

Accommodation of Business Dynamics

The RAF is currently in the process of developing its next generation Logistics Information Technology Strategy (LITS). During this transition period, numerous improved business practices are emerging, however, the existing legacy Information Technology (IT) systems are not being updated during the transition. A KBS can provide an IT platform for documenting and implementing emerging improved business practices in the interim period before the new IT system is delivered.

Intelligent Tutor

Knowledge-based systems can be designed to provide extensive advice messages, explanation and general information to assist and educate RMs as they use the system. In addition, because the rule base underlying a KBS is based on expert knowledge, the resulting decisions and recommendations are both consistent and explainable, thus lessening the negative effects of inexperience and human emotion.

EP Functionality and Program Structure

The initial development of Expert Provisioner was a joint effort by the RAF's Logistics Research (LR) Department and the Artificial Intelligence Applications Institute (AIAI) at the University of Edinburgh. Expert Provisioner was built in two phases.[3] First, a prototype system was developed. The EP prototype inference engine and knowledge base were implemented using the NASA C Language Integrated Production System (CLIPS) development tool. The prototype system served two purposes. First, it provided the RAF Logistics Research staff with the opportunity to learn about KBS via a *hands-on* development project. Second, the prototype development provided a technology demonstration tool that could be used to show RAF logistics decision-makers how a KBS approach could be used to assist the reprovisioning process. After the prototype system was completed and approved for further development and implementation, work began on an EP production system.

Overview of EP Production System Functionality

Like any system, EP consists of inputs, a process and outputs.

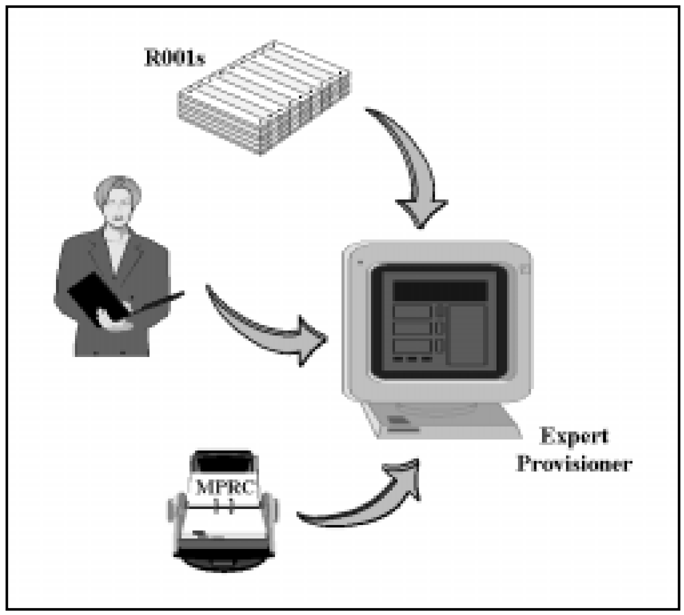

Figure 1. Expert Provisioner Inputs

EP Inputs

As shown in Figure 1, EP has three input sources: (1) the R001 document; (2) the Master Provisioning Record Card (MPRC); and (3) the Range Manager.

1. R001. The R001 provides a significant amount of item indicative data and provisioning parameter information. As part of our work, we were able to arrange for the electronic delivery of R001 data from the central computer system.

2. MPRC. The MPRC is literally a Range Manager-maintained card file of hand-written information about items. A single card exists for every item in the RAF inventory. The front of the MPRC is used to record item indicative data and other information about item peculiarities. For instance, if a price break is available when large orders are placed, that information would be recorded on the MPRC. The back of the MPRC is used to record a history of item purchases. An electronic MPRC capability was developed as part of the EP production system. MPRC shells for each item in the RAF inventory are pre-loaded by the system. The shells contain as much relevant information as can possibly be extracted from SCCS item indicative data. Range Managers have to complete the records prior to when those items arrive.

3. Range Manager. Since much of the information affecting reprovisioning OQs is not available from the other two input sources, EP is designed to prompt Range Mangers for input as required. For instance, a rule in EP may detect a recent customer demand quantity that is inconsistent with an item's historical demand pattern. The program will provide the RM with an advice message and request confirmation of demand validity or the input of corrected demand data. In fact, the design of EP is purposely that of an *intelligent assistant* rather than an authoritative decision maker.

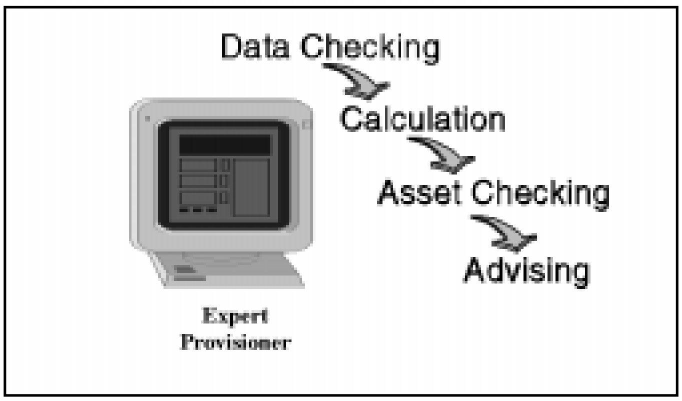

Figure 2. Expert Provisioner Rule Categories

EP Process

The processing that occurs within Expert Provisioner revolves around a rule base. The rule base development process is fairly straightforward. The first step is to identify a human expert who is highly experienced and proficient in the task of interest. Once identified, various knowledge acquisition procedures are used to transform the expert's knowledge into an orderly collection of rules for implementation in a computer program. The encoded rules are called the KBS rule base. As illustrated in Figure 2, there are four categories of EP rules: (1) data checking; (2) order quantity calculation; (3) asset checking; and (4) advising rules.

1. Data checking. The EP data checking rules are designed to focus on the item parameters that affect the order quantity calculation. For example, separate rules assess the input data elements pertaining to the accuracy and reasonableness of factors such as item administrative and purchase lead times, single and grouped demands, safety stocks and minimum buy requirements. As certain data errors are detected, EP will correct the erroneous parameter value and advise the user of the action taken. When suspect data is detected, EP produces a screen message asking the RM to investigate the potentially erroneous data and make input indicating the appropriate action.

2. Calculation. In the calculation phase, EP uses the rule-filtered provisioning parameters resulting from the data checking phase to calculate a revised reprovisioning order quantity. In addition, the EP calculation phase makes use of known price break opportunities (from the electronic MPRC) in computing the OQ. Although the item price is a key parameter affecting the OQ decision, the current central system calculation does not consider price breaks in the OQ calculation. Thus, this feature of the EP calculation phase is a significant improvement over current practice. It is also important to note that EP allows RMs to deviate from the system recommendations as they see fit.

3. Asset checking. Once an OQ is decided, Expert Provisioner uses a series of rules to search for existing RAF assets that may be used in lieu of purchasing additional stocks. These rules use data from the R001 and MPRC, in addition to databases containing disposed surplus stock records. When alternative assets are detected, EP advises the RM of where and how to obtain the stocks.

4. Advising. As mentioned earlier, the current central supply system is a legacy system that cannot be easily modified. Therefore, there are no direct electronic links between EP and the SCCS. Thus, when EP detects and corrects data errors as a result of the *firing* of data checking rules, RMs must process transactions on the central system to reconcile the item parameters on the SCCS. As the required changes are made in the data checking phase, EP creates reminder messages that are displayed during the advising phase. The update reminder messages provide the RM with all the information, including the transaction type and RAF supply manual references required to achieve central system data reconciliation. There are plans to implement an automated electronic message handling system to bridge this air gap.

EP Outputs

As shown in Figure 3 (see page 18) there are generally five types of EP outputs: (1) OQ recommendations; (2) data housekeeping assistance; (3) management and budget reports; (4) desktop analysis capabilities and help facilities; and (5) information messages. These aim to assist the RM throughout the process of reprovisioning.

Preliminary Results

Although EP is not yet fielded in all Supply Management Branches (SMB), we believe the system has already produced significant benefits. The benefits noted thus far resulted from the EP development process and from the Jaguar Supply Management Branch's trial implementation.

Developmental Benefits

In addition to being an excellent learning experience for the LR staff, the EP development process has resulted in both quantifiable and intangible benefits for the RAF.

Reduced safety stocks. During the rule base development process, we constructed a rule which checks that selected items supplied directly to RAF customers by contractors have a Depot Working Stock Level (DWSL) parameter set to zero as required by RAF procedures. A DWSL of zero ensures no depot safety stocks of the items are held. In December 1997, we conducted a spin-off analysis of supply central system data to discover that the vast majority of over 12,000 active direct supply items have

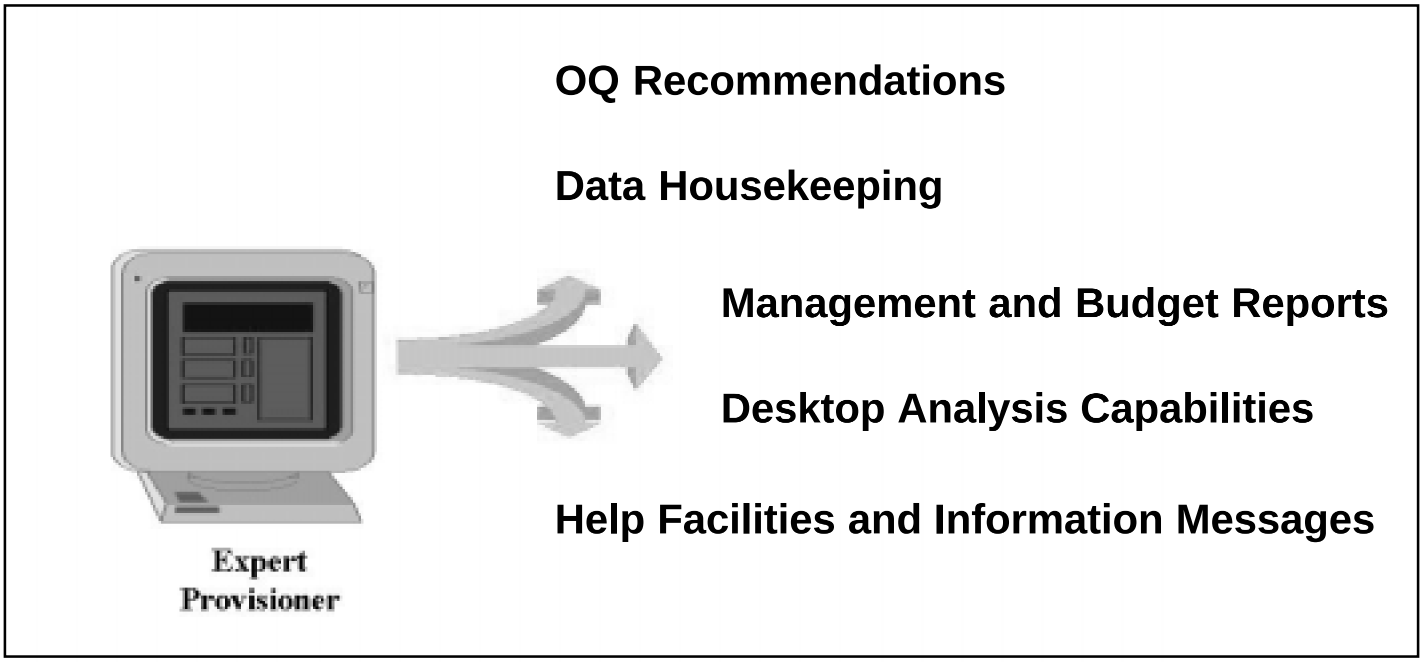

Figure 3. Expert Provisioner Outputs

DWSLs greater than zero. Further analysis revealed that the supply computer terminal screens did not allow Range Managers to input a DWSL value of zero. Because of the erroneous DWSL values, the RAF is currently holding more than £2.7M ($4.5M) in excess depot stocks. As a result of our analysis, the RAF supply policy staff directed a correction of the computer terminal screen input limitations and initiated a central system data sweep to correct the item DWSLs and preclude future safety stock procurements of direct supply items.

Surplus stock retrieval opportunities. A second significant benefit resulting from EP development involved RAF surplus stocks held by Military Aircraft Spares Limited (MASL). MASL is under contract to the MOD to act as the disposal agent for surplus assets. As the RAF disposes of surplus stocks, the stock balances are removed from SCCS records and recorded in the MASL inventory control system. Until MASL sells the surplus stocks, they are available for issue to RAF needs. However, since Range Managers do not have visibility of MASL stock balances, retrieval of MASL stocks seldom occur. In a spin-off analysis published in February 1998[4], we discovered that over the last two years, there were nearly 2,000 opportunities where the retrieval of MASL stocks could have fully, or partially, satisfied £1.3M ($2.16M) worth of RAF reprovisioning requirements. As a result we have implemented a rule that will use MASL data to detect the existence of available surplus stocks and preclude unnecessary procurement actions.

Electronic Requisition Requests

As part of the EP development process, arrangements were made for the creation and transmission of electronic R001 Request for Requisition documents. This capability speeds the delivery of R001s for Range Manager processing and could potentially lead to a significant reduction in paper printing and handling costs. It has also realised an estimated saving of some £681K ($1.128M) on work that would have been done under the LITS Tranche I Order Management software development effort.

EP Trial Implementation Benefits

A trial of the EP software was initiated in two Range Management cells in January 1998. During the trial, Range Managers processed their R001s without the benefit of EP and then later reprocessed the same R001s electronically through EP. The goal of this exercise was twofold. First, the trial was used to obtain feedback regarding EP functionality and usability. Second, trial data was used to assess EP's usefulness in detecting potential parameter errors and validating the effectiveness of the individual rules in EP.

User Feedback

As expected, the first month of the trial generated a great deal of feedback from the users. That feedback often led to adjustments in the software. In addition, we encountered and worked through computer hardware connection problems to successfully connect all trial participants to the EP software. Therefore, the analysis results from the first month were somewhat limited, but nonetheless, instructive. The customer feedback was clearly supportive of EP implementation. In general, the trial users advised that the rule base is robust and helpful. In addition, user feedback suggested that the program structure closely followed current R001 processing procedures. User feedback also indicated that EP provides important intangible benefits. Specifically, the trial highlighted EP's value in promoting user computer skills development, as a training aid and as a data analysis tool.

Computer Skills Development

Although many of the trial users are not PC-literate, they indicated the program is easy to use, and thus they are developing important rudimentary computer skills as they use EP. We believe that the computer skills acquired via the implementation of EP will significantly ease the implementation of LITS.

Training Value

A second intangible benefit of the EP trial implementation resulted from the existence of the numerous help features. The trial participants advised us that these features are very useful, particularly to more inexperienced Range Managers. Clearly, using EP is improving Range Management skills in a way that will benefit the RAF logistics community in both the short and long terms.

Data Analysis Capability

The EP system includes the DataProv package, along with the data required to process desktop DataProv queries. EP trial users have advised us that they have used this capability extensively to identify and correct erroneous provisioning parameters that would not have been otherwise detected. Although not easily quantifiable, there is no doubt that those parameter corrections are improving the quality of subsequent provisioning decisions.

Trial Data Analysis

Although, the first month of the trial was a learning process with continuous program development, we were able to glean some useful data from the results in terms of rule base effectiveness and rule base update needs.

Rule Base Effectiveness

Analysis of a sample of 30 R001s that were processed during the first month of the trial (January 1998 data) revealed that seven of the 30 items satisfied all 10 criteria for automatic ordering qualification. This is an important result that has the potential to reduce RM workloads and streamline the provisioning process. Further analysis of the rule base performance for the 30-item sample indicated that, on average, EP highlighted 3.7 item parameters per R001 that required RM attention, compared with 2.7 flagged parameters for R001s processed without EP. We believe this result gives an early indication that the EP rule base performs a more accurate and comprehensive check of provisioning parameters than is being conducted by the RMs.

Rule Base Updates

Analysis of the trial data also indicated that additional rule base modifications and additions may be appropriate. For instance, one EP rule checks for price break opportunities *fires* for virtually every R001 and may need modification to prevent annoying EP users when price breaks are not applicable. We are also using the analysis results to determine if there are data checks that are not accommodated in the rule base. As such discoveries are made via analysis of the EP trial data, we will update the EP rule base to maximise the system benefits.

Future EP Development

Following the implementation of the EP production system, we anticipate expanding the rule base to incorporate functionality for assisting Range Managers in making repair quantity decisions for suitable items. Additionally, we envision the development of a data feedback link to the central supply system for the electronic passage of item parameter update messages. Finally, as mentioned earlier, the RAF is in the process of defining and implementing a new Logistics Information Technology Strategy (LITS). As the development of EP has progressed, LITS development personnel have expressed interest in integrating elements of EP into LITS. We are currently coordinating with the LITS office to determine how integration of EP may be taken forward as a decision support system for the new logistics IT system.

Expert Provisioner provides the RAF logistics community the ability to capture expert reprovisioning knowledge and implement that knowledge across the reprovisioning community in a way which promotes best business practices and trains inexperienced Range Managers while simultaneously improving order quantity decisions.

Summary and Conclusion

The initial implementation of EP within one of the four support management directorates, at RAF Wyton, was completed in July 1998 and significant business and financial benefits have already been realised. Those that can be measured total some £4.25M ($7.36M). This coverage will be expanded to nearly 100 percent of all RAF consumable managers with the delivery of a new IT platform, due in the first quarter of 1999.

We believe the continued development and implementation of the Expert Provisioner KBS represents a significant step forward in the efficient management of RAF consumable item inventories. EP provides the RAF logistics community the ability to capture expert reprovisioning knowledge and implement that knowledge across the reprovisioning community in a way which promotes best business practices and trains inexperienced Range Managers while simultaneously improving order quantity decisions.

In addition, EP provides the RAF with a flexible interim IT platform which can be used to implement new, improved reprovisioning procedures pending the delivery of the next generation RAF logistics IT system. The usefulness and benefits of applying KBS as described in the literature[5] would seem to have been realised.

Notes

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4. Reynolds, Steven B., Major, USAF, *Military Aircraft Spares Limited—Analysis Project Report*, published by Logistics Research, RAF Wynton, 1998.
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(Continued on middle of page 42)

Deployment and Sustainment Research and Development (R&D)

The Deployment and Sustainment Division (AFRL/HES) conducts research and development to improve Air Force logistics functions at the retail and wholesale levels and to protect Air Force personnel in potentially toxic environments at deployed locations. The division is part of the Air Force Research Laboratory and is located at Wright-Patterson AFB Ohio. Applications cover a broad spectrum of field, depot and space operations with customers throughout the Air Force, Department of Defense, other government agencies, academic institutions and US industry.

The following are brief descriptions of selected ongoing research projects. Readers interested in obtaining more information about these projects are encouraged to contact the program managers listed or visit the Deployment and Sustainment Division's home page at http://www.alhrg.wpafb.af.mil.

AIRCRAFT BATTLE DAMAGE ASSESSMENT AND REPAIR (ABDAR) TECHNOLOGY

OBJECTIVE: Enhance USAF ABDAR capability by providing battle damage assessors, technicians and engineers with quick and easy access to assessment and repair information.

APPROACH: A contracted research effort began in August 1995 and will be accomplished in four major phases. In Phase I, a requirements analysis was performed to identify information required by assessors and engineers to assess damaged aircraft. In Phase II, the ABDAR demonstration system was designed based on the requirements defined in the Phase I study. The design focuses on providing ABDAR information to the user through a portable maintenance aid (PMA). The PMA will contain all of the information required by the user, including assessment and repair logic, technical orders, part information, wiring diagrams, schematics and troubleshooting data. A graphical user interface will allow the user to easily access and comprehend ABDAR information. The Phase III effort, currently in progress, involves implementing the software design, authoring technical data and integrating the system. Data for a specific test-bed aircraft is being developed for presentation on the PMA. Finally, Phase IV will involve final system enhancements and testing to evaluate system effectiveness and user acceptance.

EXPECTED PAYOFFS: Fast and accurate battle damage assessment and repair will lead to improved combat effectiveness by reducing the time to get damaged aircraft back to mission capable status. Less experienced users will have better access to ABDAR information, reducing the reliance on highly trained assessors. Deployment capabilities will be enhanced by minimizing the amount of paper technical data and supporting information presently required by the user. (Capt Michael Clark, AFRL/HESR, DSN 986-7042, (937) 656-7042, mclark@alhrg.wpafb.af.mil)

APPLICATION OF MONOCULAR DISPLAY DEVICES (MDDs) AND ALTERNATIVE COMPUTER CONTROL DEVICES (ACCDs) TO AIRCRAFT MAINTENANCE

OBJECTIVE: Assess promising new monocular display and alternative computer input technologies for the presentation and retrieval of maintenance technical information for flight line and depot maintenance.

APPROACH: A series of experimental studies is being conducted to evaluate the devices for supporting various maintenance tasks and remove-and-replace actions. Initial efforts focused upon evaluating MDDs and ACCDs in a variety of environments. Current efforts focus on testing a variety of newly developed MMD and ACCD technologies. MDD devices include occluding and see-through displays. ACCDs include state-of-the-art speech-based controls and electromyographic (EMG) controls. EMG devices use electrical signals accompanying muscle contractions to input user commands. Seven studies and numerous usability evaluations have been conducted since 1991. The studies have demonstrated significant improvements in the performance of technicians using MDDs under a variety of conditions and for a variety of types of tasks. Initial ACCD studies using speech recognition technology have demonstrated significant benefits from the technology, but have also identified problems encountered due to noise. Planned studies using advanced speech recognition and special microphones placed in the ear are expected to overcome this problem. This work is being conducted as a joint effort with the AFRL Crew Systems Interface Division.

EXPECTED PAYOFF: Improved maintenance performance, reduced maintenance downtime and reduced maintenance costs. (Barbara Masquelier, AFRL/HESR, DSN 986-7005, (937) 656-7005, bmasquel@alhrg.wpafb.af.mil)

DEPLOYABLE WASTE MANAGEMENT SYSTEM (DWMS)

OBJECTIVE: Develop and evaluate a deployable waste management system to support bare base operations. The system will process the primary types of waste produced, including municipal solid waste, medical waste, petroleum, fuels, waste water and air emissions.

APPROACH: The bare base waste management system will consist of a set of small, waste-handling modules, which are loadable on pallets for air transport. Some examples of possible modules are a: (1) reactor to process municipal solid waste, medical waste, waste fuels and other petroleum-based wastes; (2) scrubbing system for exhaust gases that utilizes and evaporates waste water; (3) reactor to treat black water solids; and (4) containerization system for return of other wastes. The first phase of this work will consist of an 18-month systems optimization study to look at all aspects of this proposed system from the Air Force perspective. Power requirements will be analyzed, and operability factors, logistics impacts and cost drivers will be examined. Engineering analyses will be performed for each technology proposed for each module, along with the interconnections of each technology, in order to ensure the overall system is evaluated. Users will be polled to determine the operational requirements of the system, both from the technology itself and the logistics of deploying such a system. Engineering and life cycle costing analyses will be performed for all possible technology candidates for each module and the overall system itself. Following this 18-month effort, the components will be integrated to form the Waste Management Demonstration System. The resulting system will then be evaluated in a realistic operational environment, possibly at a Silver Flag Exercise site. This task will be completed by 2001. The work is being conducted as a joint effort with the Air Force Research Laboratory, Airbase and Environmental Technology Division.

EXPECTED PAYOFF: Provide cost-effective processing and neutralization of waste products produced during bare base operations. Proper management of the waste materials will provide a safer, healthier environment for Air Force personnel, reduce the amount of cleanup required at the completion of the operations and reduce environmental damage—all which promote better relations with the host nation. (Jill Ritter, DSN 986-4391, (937) 656-4391, jritter@alhrg.wpafb.af.mil)

JET FUEL HEALTH EFFECTS RESEARCH

OBJECTIVE: Protect the warfighter from adverse health effects associated with using battlefield fuels while maintaining operations tempo.

APPROACH: JP-8 is the battlefield fuel for US and NATO air and ground operations. As it is designed to serve as the single theater fuel, JP-8 will significantly reduce the logistics burden demanded by the shipment, storage and employment of multiple fuels. JP-8 is primarily kerosene and has proven to be safe and effective during normal use as a turbine engine fuel. To ensure safe use of the fuel during military specific operations, scientists study potential and observed human health effects of JP-8. The fuel is tested in ways that are consistent with how the warfighter is exposed in the field. Examples include fuel vapor, fuel aerosol and skin exposures. Vapors and aerosols are inhaled into the lungs. Vapor exposures to JP-8 have been studied since the 1970s and are generally low due to the fuel's low vapor pressure. Aerosol exposures are not well studied and continue to be a concern in certain cold weather situations where actual aerosol exposures can be significant. Skin exposures may be the most common exposure and have received considerable attention. The research is addressing how quickly and in what quantity JP-8 penetrates the skin. JP-8 will likely be the parent fuel for future needs through the year 2020. Fuels such as JP-8+100 (100°F increased thermal stability) and JP-900 are currently fielded or are under development (respectively) to answer the needs of new weapon systems. As the fuels are enhanced, health effects research must parallel the development to ensure the usage is safe and prevent mission degradation to users exposed to the fuel.

EXPECTED PAYOFF: Sustained flying operations tempo and other battlefield operations without adverse health effects. Fuels under development can be fielded more quickly when potential adverse health effects are minimized. (Maj Tom Miller, AFRL/HEST, DSN 785-5150, (937) 255-5150, millert@falcon.al.wpafb.mil)

INTEGRATED TECHNICAL INFORMATION FOR THE AIR LOGISTICS CENTERS (ITI-ALC)

OBJECTIVE: Improve, standardize and integrate technical and managerial information and make it more readily available at the job-site to improve the performance of aircraft programmed depot maintenance (PDM) activities.

APPROACH: This effort had two phases. In Phase I, a detailed requirements analysis of current PDM operations at all Air Force Air Logistics Centers (ALCs) was completed. The focus of Phase I was on PDM with a limited evaluation of assemblies, modules and units. Information modeling was used to develop *as-is* and *to-be* functional, data and process models that represent PDM operations and information requirements. Dynamic simulations were used to investigate process changes and improvements. Products from the Phase I effort include an architecture report documenting the results of a depot-level requirements analysis, a business case in which depot process improvements have been identified, functional specifications and a top-level design for an integrated information capability. Phase I was completed in April 1996. In Phase II, the results of the requirements analysis phase were used to design, develop and test a demonstration-level integrated maintenance information capability for supporting PDM activities. Phase II activities included creating advanced techniques to improve the inspection process, developing new tools to facilitate the collaboration between technicians and engineers to resolve critical repair issues, developing new user interface concepts and testing advanced hardware and software technology. Phase II began in December 1996 and was completed in September 1998.

EXPECTED PAYOFF: Payoff to the Air Force includes specifications for developing a full-scale, depot-integrated maintenance information system for operational use. In addition, the ITI-ALC effort provides the ALCs with an independent review of the current PDM process and possible changes or areas for improvement, to increase efficiency, lower operating costs and improve technician performance. (Paul Faas, AFRL/HESR, DSN 986-4360, (937) 656-4360, pfaas@alhrg.wpafb.af.mil)

LOGISTICS CONTROL AND INFORMATION SUPPORT (LOCIS)

OBJECTIVE: Provide logistics personnel at all levels within the wing-level complex proactive access to real-time, accurate information needed for decision support and more effective utilization of logistics resources.

APPROACH: The LOCIS effort is researching and developing technologies for an enhanced command and control capability for wing-level logistics personnel. LOCIS will provide easy access to logistics information to support proactive problem identification and resolution. LOCIS technologies will automatically collect and synthesize information required for key logistics decisions. The most important pieces of information will be retrieved from existing maintenance, supply, munitions and fuels information systems. Using advanced information technologies, LOCIS technologies will automatically supplement this information with data from legacy information systems to provide immediate, useful information to logistics decision-makers. In addition, LOCIS will use automated data collection technologies to supplement existing data with real-time data. LOCIS technologies will provide logistics decision-makers with a look-ahead simulation capability to identify problems in the planning/replanning process.

EXPECTED PAYOFF: LOCIS will provide logistics personnel the information and tools they need to better perform their duties. Through the use of real time, accurate information and the application of advanced decision aids, logistics personnel will be more effective in the day-to-day use of their assets and in short-notice deployment operations. (Barbara Masquelier, AFRL/HESR, DSN 986-7005, (937) 656-7005, bmasquel@alhrg.wpafb.af.mil)

COGNITIVE PROCESS MODELING (CPM)

OBJECTIVE: Develop and demonstrate advanced modeling and simulation techniques that can easily generate high fidelity computer models of human behavior, as well as state-of-the-art intelligent agents for use in synthetic environments, distributed simulations and information systems.

APPROACH: The maturation of intelligent agent technology has created the opportunity to apply such technology to the modeling and simulation of human and organizational behavior and the development of advanced human-computer interfaces. As for modeling human behavior, intelligent agent modeling techniques are applied to the development of advanced organizational models of command and control echelons, technical controllers and human performance. The development of such models will increase the realism of joint synthetic battle-space exercises while reducing their cost. In addition, such models will allow the simulation of information operations. One of the major goals of the effort is to provide users with a flexible scenario generation capability which will enable them to easily adapt such models to a wide variety of exercises with minimal effort.

In the area of human-computer interfaces, we are applying intelligent agents to the creation of interfaces that use agents to selectively monitor and react to state-changes in the world. When user-specified conditions are met, the agents become active and perform actions on behalf of the user. New capabilities which are being developed include standard user-interface profiles (by position), the ability for a user to request customized information (from disparate data systems) and *look-ahead* and *what if* scenario planning tools. While our target demonstration is AMC’s Tanker Airlift Control Center (TACC), the technology developed in this effort will be applicable to a wide range of logistic applications. It is intended that (operational) users with no programming experience will be able to program the intelligent agents, thus allowing users to determine what information they wish to track and how they want the intelligent agents to respond to changes in the world. Our goal is to make the tasking of agents no more difficult than using a spread sheet. In addition, the agents will operate over computer networks, thus allowing users to monitor and retrieve information at remote locations

EXPECTED PAYOFF: With the Air Force and the DoD relying more heavily on modeling and simulation technology for a variety of applications, including acquisition, testing, training, war gaming, mission rehearsal and operational representation of the battle-space, the development of advanced intelligent agent technology will satisfy critical technological voids in these simulations by providing realistic representations of human cognition, as well as advanced agent technology to enhance the effective utilization of military information systems. (Dr. Michael J. Young, AFRL/HESS, DSN 785-8229, (937) 255-8229, myoung@alhrg.wpafb.af.mil)

LOGISTICS CONTINGENCY ASSESSMENT TOOL (LOGCAT)

OBJECTIVE: Demonstrate new technologies and processes to improve the deployment planning process, reduce deployment footprint, reduce deployment response times and use deployment resources more efficiently and effectively.

APPROACH: The Logistics Contingency Assessment Tool (LOGCAT) is a vision for improved wing-level deployment planning and replanning. Currently, the LOGCAT Vision is comprised of four integrated initiatives, Survey Tool for Employment Planning (STEP); Unit Type Code Development, Tailoring and Optimization (UTC-DTO); Beddown Capability Assessment Tool (BCAT); and Logistics Analysis to Improve Deployability (LOG-AID). The STEP will use advanced integration of computer hardware and software to automate the collection, storage and retrieval of deployment site survey information. The STEP consists of three major subsystems: a suite of computerized/multimedia site survey data collection tools, a deployment site knowledge data base and a graphical and collaborative user interface for retrieving information from the deployment knowledge data base. Transition of the STEP to the Standard Systems Group (SSG) for operational implementation was completed in Fiscal Year 1998. UTC-DTO uses advanced software to automatically develop UTCs, automatically tailor UTCs based on individual deployment scenarios and optimize the packing of UTC equipment on to 463L cargo pallets. BCAT uses advanced database design to compare deployment site force beddown capabilities against deploying force beddown requirements and produce a list of resource shortfalls. Transition of the BCAT to the SSG for operational implementation was also completed in Fiscal Year 1998. LOG-AID is analyzing the deployment process firsthand to define requirements, identify additional opportunities to improve deployment-planning processes. Additional planning tools and processes will be developed and integrated with the appropriate BCAT, STEP and UTC-DTO tools to form a demonstration deployment planning system. The deployment planning demonstration system will then be tested under field conditions.

EXPECTED PAYOFF: Improved wing-level deployment planning and execution will increase Air Force combat capability. Reducing the mobility footprint will reduce requirements for scarce airlift assets, enabling deployment of additional combat capability. Reducing deployment response time will increase the deterrent effect of our military forces on distant enemies and allow policy makers to respond more quickly to aggressive actions of distant enemies should deterrence fail. More efficient and effective use of mobility resources will allow the Air Force to maximize its power projection capabilities. (Capt Dwight Pavek, AFRL/HESR, DSN 986-4557, (937) 656-4557, dpavek@alhrg.wpafb.af.mil)

LOGISTICS RESEARCH REQUIREMENTS SURVEY

OBJECTIVE: The primary objective is to survey logistics personnel to identify problem areas and needs which can be effectively addressed in future research programs. The initial areas of investigation will be the supply and transportation environments. The ultimate goal is to identify research opportunities that directly support the Expeditionary Aerospace Force (EAF) and mobility capabilities.

APPROACH: The survey team will begin interviews with supply and transportation personnel to determine key themes and concepts. Inputs will be solicited from a wide range of specialties, ranks and skill levels. Questions will be created and validated with follow-up interviews. Also during this time, other members of the team will be evaluating web-based survey tools and statistical analysis software packages. A pilot study will be run prior to a more extensive release. The results will be analyzed for both web survey viability and potential research targets. If successful, a more exhaustive survey will be conducted throughout the logistics arena. The most promising opportunities will be developed into laboratory research programs to develop and test the needed capabilities.

EXPECTED PAYOFF: The laboratory will be able to respond more quickly to current logistics research needs. Technologies to reduce costs and increase operational capabilities will become available to the warfighter. (Cheryl Batchelor, AFRL/HESR, DSN 986-4392, (937) 656-4293, cbatchel@alhrg.wpafb.af.mil)

DEPOT OPERATIONS MODELING ENVIRONMENT (DOME)

OBJECTIVE: Develop and test advanced process analysis technologies which will significantly improve the efficiency and reduce the costs of key logistics support processes within the ALCs.

APPROACH: A process engineering environment will be developed which will electronically link the operational wings and the depots, so that both can participate equally in process improvement efforts that directly affect them. This integrated environment will include distributed collaboration and process modeling capabilities. These tools will permit online interaction, across the country, in a variety of modes and applications and it will allow the users to jointly investigate the effects of process change scenarios. This will help reduce risks involved with the implementation of desired process improvement changes. A methodology for using the environment will also be developed. Plans are underway for installation and field testing of the system at the Warner-Robins ALC and Mountain Home AFB.

EXPECTED PAYOFF: DOME will provide the technology to perform smarter streamlining of logistics processes, resulting in improved ALC efficiency, productivity and response time to the warfighter. (James McManus, AFRL/HESS, DSN 785-8049, (937) 255-9940, jmcmanus@alhrg.wpafb.af.mil)

Editor's Note: See Vol. XXII, Number 1 of the Air Force Journal of Logistics, 22-25. It contains the in-depth article, "Depot Operations Modeling Environment (DOME): A Collaborative Tool for Improving the Wing-to-Depot Logistics Process," written by Captain Frank Simcox, Captain Joseph Romero and Samuel Kuper.

INTEGRATED REQUIREMENTS SUPPORT SYSTEM (IRSS)

OBJECTIVE: Enable more efficient and accurate definition, analysis and management of weapon system requirements throughout the planning and acquisition processes.

APPROACH: IRSS is a response to the Air Force Directorate of Operational Requirements' vision of a *World Class Requirements Support System*. MAJCOM participants have defined the IRSS functional requirements through collective application development sessions and spiral development. IRSS was founded on the results of 6.2 exploratory research (Requirements Analysis Process in Design for Weapon Systems) and a study of the stand-alone, unique systems designed to meet the needs of the creating command. The IRSS analysis objective is to exploit MAJCOM unique systems and develop a single, best practice toolset for Air Force-wide use. Field demonstration and technology transition will be completed during Fiscal Year 1999.

EXPECTED PAYOFF: IRSS will reduce the effort needed to produce operational requirements documents that have Air Force-wide coordination and visibility. IRSS is a common collaboration forum for the requirements community, and it provides an entry point for functional participants (logisticians, intelligence planners, etc.). IRSS also has the ability to capture operational requirements as they evolve throughout the planning and acquisition cycle. The system will become a working application that generates official archives without additional effort. Lastly, IRSS has the potential to become a standard point of departure for requirements process innovations and could provide a suitable testing environment for innovative requirements management techniques. (Capt David Pena, AFRL/HESS, DSN 785-9474, (937) 255-9474, dpena@alhrg.wpafb.af.mil)

MODULAR AIRCRAFT SUPPORT SYSTEM (MASS)

OBJECTIVE: Design, build and demonstrate proof-of-concept aerospace ground equipment (AGE) that supply electricity, cooling air, nitrogen, hydraulic and related utilities for aircraft maintenance in modular, multi-function carts. Increase the affordability and reduce the airlift required to deploy AGE through modular designs with advanced concepts and technologies.

APPROACH: The MASS program is supported through an Integrated Product Team (IPT) with members from the Air Force support equipment community and laboratories. The IPT will jointly develop requirements, provide customer input, coordinate R&D efforts and support technology transition. Phase I included a series of MASS design studies emphasizing technology assessment, cost/affordability analysis and reliability/maintainability analysis of AGE. This early research resulted in a large knowledge base of existing problems and preliminary specifications for MASS machines. Phase II will bring this concept through a research and development cycle culminating in the creation of a MASS prototype unit and field test/demonstrations in Fiscal Year 2000.

EXPECTED PAYOFF: Introduction of modular support equipment will reduce the deployment footprint in a direct, objective way. Making support equipment smaller, multifunction and modular allows for reduced numbers of ground support equipment items, while maintaining flexibility. Maintenance modularity allows for reduced down time for repairs, increasing availability. At the same time, MASS machines will be more reliable and maintainable than current support equipment, resulting in reduced MASS ownership costs in manpower, spares and training. Cost savings should span from initial acquisition through disposal.

(Matthew Tracy, AFRL/HESS, DSN 785-8360, (937) 255-8360, mtracy@alhrg.wpafb.af.mil)

Editor's Note: See Vol. XXI, Number 2 of the Air Force Journal of Logistics, 13-18. It contains the article, "An AGE of

Opportunity" written by Matthew Tracy, Captain Dwight Pavek and First Lieutenant John Schroeder.

READINESS ASSESSMENT AND PLANNING TOOL RESEARCH (RAPTR)

OBJECTIVE: Develop and demonstrate innovative methods and tools to assist Air Force logistics agencies in the preparation, planning and managing of organizational changes and process improvements.

APPROACH: This advanced development research program will assist logisticians and managers in successfully implementing changes in their organizations. First, the program will examine past change efforts, such as: reengineering, Lean Logistics and Pacer Lean to understand organizational barriers to change. Second, the program will design an organizational survey that will identify these important issues to an organization and offer remedies to address them. Third, the program will build a tool that integrates the organizational assessment survey with a project planning function. The tool will enable an organization preparing for change to assess cultural, technological and strategic issues within their organization. Based on the assessment data, the tool will offer suggestions on best tools and methods for that particular organization to utilize in their change effort. The tool will also contain a smart repository of lessons learned, both pro and con, from organizations that have been through similar change efforts in the past. Information in the repository will be utilized during the design of the to-be process to reduce risk, save time and improve the quality of the results.

EXPECTED PAYOFF: RAPTR will assist Air Force users in achieving their process improvement goals by addressing the users' organizational culture, strategy and technology issues. This tool will help users optimize their functional processes, resulting in dramatic improvements in critical performance measures such as cost, quality, service and speed. The ultimate goal of RAPTR is to increase warfighting capabilities by streamlining logistics processes and reducing logistics costs. (Capt Cassie B. Barlow, AFRL/HESS, DSN 785-8363, (937) 255-8363, cbarlow@alhrg.wpafb.af.mil)

Future Research Areas

Enhanced Diagnostics Support for Technicians

This program will develop an advanced diagnostics capability to improve the diagnostic success rates for both hardware and software based problems. The effort will begin with a detailed study of the problem to identify the causes of diagnostic failures using current technologies and the operational capabilities/ requirements of the target aircraft systems. Concurrently, a review of recent developments in fault diagnosis-like tasks in other technical areas (medicine and software verification/debug) to identify approaches (such as artificial intelligence, computational logic and neural nets), with potential for application to aircraft diagnostics will be conducted. Once the nature of the underlying problems, performance requirements and potential diagnostic enhancement approaches have been established, work will begin to develop and test the selected technologies.

USAF Logistics Policy Insight

Flying Crew Chief (FCC) Program Changes

The FCC program was originally established to compensate crew chiefs who were required to accompany their aircraft to austere locations or other places where qualified maintenance support did not exist. The MAJCOMs found it necessary to often require maintenance personnel to accompany aircraft even though the mission did not meet the FCC program requirement of supporting maintenance at remote bases. The program was not meeting mission requirements as it was originally defined.

Program objectives have been redefined to:

1. Provide qualified maintenance support for aircraft at locations other than home station.

2. Reimburse maintenance personnel for maintaining special qualifications and performing regular aerial flight.

With changes in objectives, the program applies to maintenance personnel who are required to fly regularly as a result of (1) the DoD, USAF, MAJCOM or other higher authority's written policies directing FCCs to accompany their aircraft for mission accomplishment; and (2) technical order (TO)-directed in-flight maintenance (for example, helicopter functional check flights). This revision also more clearly identifies situations that would not qualify for the FCC program. These include:

- Occasional flights where the aircraft is used as transportation in lieu of commercial air.
- Incentive or indoctrination flights where the aircraft departs from and returns to home station.
- Deployments where additional maintenance personnel are required at the designated location to supplement assigned maintenance personnel.

The revised program allows two FCCs per aircraft and also permits an assistant FCC (who can be a 5-level airman first class who possesses the aircraft special experience identifier). The assistant FCC is not required to meet all requirements that the primary FCC must meet. The assistant must also accompany a fully qualified FCC. There were also minor changes to the reporting requirements. In addition, a simple waiver process was added to provide units with information on how to obtain waivers. The Air Force Instruction (AFI) states that waivers are processed to MAJCOMs and then AF/ILMM. If the MAJCOM disapproves, it is returned to the unit.

Interim Change (IC) 98-1 revises *AFI 21-101, Maintenance Management of Aircraft*, and is posted on the Air Force publishing site at http://afpubs.hq.af.mil and on the Air Force publishing distribution library (AFPDL). (CMSgt Funk, HQ USAF/ILMM, DSN 227-8164)

AFIT The Doorway to Logistics Success

Student research is a key component of the Air Force Institute of Technology's Graduate School of Logistics and Acquisition Management programs. All students, working either alone or in teams of two, complete a master's thesis during their course of study. Many of the thesis research efforts are sponsored by agencies throughout the Department of Defense. The theses listed below were selected for various awards and they focus on *real world* problems. Copies of all AFIT theses are available through the Defense Technical Information Center (DTIC), Cameron Station, Alexandria VA 22304-6145, DSN 284-7633.

The Air Force Institute of Technology Class of 1998S graduated on 15 September 1998. The following students were recognized for their outstanding achievements while obtaining Master of Science degrees.

Commandant's Award

(The most exceptional master's thesis research, an outstanding contribution to scientific, management or engineering knowledge)

Title: *Impact of Facilitator Co-Location and Alignment on the Efficacy of Group Support Systems Employed in a Distributed Setting*
Author: First Lieutenant Jeffrey Lea
Advisor: Major Paul Thurston and Alan Heminger, PhD
Sponsor: AFRL/HESS, Wright-Patterson AFB OH

Group Support Systems (GSSs) are a combination of hardware, software and human facilitation designed and employed to increase the effectiveness and efficiency of decision-making groups. Engineers at the Sustainment Logistics Branch of the Air Force Research Laboratory have recently proposed employing the technology in a distributed setting to conjoin geographically separated members of decision-making groups in order to facilitate the reengineering of logistics processes in an any-place/any-time environment.

To date GSSs have been studied and employed primarily in the same-time/same-place setting. Consequently, little is known or understood concerning the effects these systems may have on group dynamics when employed in the distributed setting.

This thesis examines how two elements of GSS configuration, the location and alignment of the meeting facilitator, may impact system users' perceptions of situational equity, their attitudes towards the efficacy of the technology, their information-sharing behavior and the quality of decisions reached by user-groups. The results of the work indicate that isolation of the facilitator from meeting members is desirable, and that facilitator neutrality is essential to the efficacy of such systems deployed in the distributed setting.

Dr. Leslie M. Norton Pride-in-Excellence Award

(Outstanding Quality; three recipients)

Recipient 1
Title: *Manned Versus Unmanned Reconnaissance Air Vehicles: A Quantitative Comparison of the U-2 and Global Hawk Operating and Support Costs*
Authors: Captain Brian Kehl and Captain Michael Wilson
Advisor: Lieutenant Colonel Terry Adler
Sponsor: ASC/RAV, Wright-Patterson AFB OH

This research provides a brief history of the advancements in technology that have made unmanned flight for reconnaissance purposes an operational reality. It attempts to provide a good comparison of operating and support costs between the first High Altitude Endurance (HAE) Unmanned Aerial Vehicle (UAV), the Global Hawk, and the system it is slated to compliment/replace, the U-2. The Air Force's Cost-Oriented Resource Estimating (CORE) model and the expertise of the Reconnaissance Mission Area Group (RMAG) located at Wright-Patterson AFB OH, were used to develop a realistic operating and support cost for a fleet of Global Hawk air vehicles in Fiscal Year 1997 dollars. Actual Fiscal Year 1997 data was used to develop a U-2 estimate for comparison purposes. It was found that when the Global Hawk was compared to the U-2 on an equal annual flying hour basis, only 14 Global Hawks were needed to provide the same number of reconnaissance flying hours as 35 U-2s. The Global Hawk's smaller fleet size and manpower requirements resulted in a flying hour cost savings of approximately 49 percent as compared to the U-2. In order to address the fact that an hour of Global Hawk flight time is not equal, on a one-to-one basis, with a U-2 hour of flight time, sensitivity analyses were conducted on the Global Hawk point estimate to help provide a range of values for comparison to the U-2 data.

Recipient 2
Title: *Impact of Facilitator Co-Location and Alignment on the Efficacy of Group Support Systems Employed in a Distributed Setting*
Author: First Lieutenant Jeffrey Lea
Advisor: Major Paul W. Thurston and Alan R. Heminger, PhD
Sponsor: AFRL/HESS, Wright-Patterson AFB OH
(See Commandant's Award)

Recipient 3
Title: *A Return on Investment Model for Air Force Technology Transfer*
Author: Captain Bradley McDonald
Advisor: Major Richard Franza
Sponsor: AFRL/XPTT, Wright-Patterson AFB OH

Air Force policy states the fundamental reason for participating in technology transfer is to maximize the return on investment (ROI) on research and development (R&D) funds. Public law dictates that federal agencies, including the Air Force, spend no less than 0.5 percent of their overall R&D budget in the pursuit of technology transfer. However, there is currently no ROI model available to the decision-maker for the evaluation of alternative transfer opportunities. This research effort developed a model that measures the ROI of individual cooperative research and development agreements (CRDAs) on the basis of the objective and subjective benefits amassed. The model results assist the decision-maker by providing a relative ranking of each transfer opportunity in comparison to one another. A sensitivity analysis method and results are included which identify definite regions of alternate "optimal" choices depending on the weight given to objective and subjective benefits. Consequently, the decision-maker is provided with a flexible model for use in maximizing ROI.

Project Management Institute (PMI) Award

(Clear understanding and command of project management techniques)

Title: *A Return on Investment Model for Air Force Technology Transfer*
Author: Captain Bradley McDonald
Advisor: Major Richard Franza
Sponsor: AFRL/XPTT, Wright-Patterson AFB OH
(See Dr. Leslie M. Norton Pride-in-Excellence Award)

Air Force Historical Foundation Award

(Significant contribution to an understanding of the historical factors affecting an Air Force or DoD problem, event, or process)

Title: *Republic of Korea Weapons Acquisition Through the Post-Cold War and the Case of the SAM-X Project: Implications for US-ROK Relations*
Author: Captain George Hutchinson
Advisors: Craig M. Brandt, PhD and Major Daryl Hauck
Sponsor: Institute for National Security Studies, HQ USAF/DFES, USAF Academy CO

The dissolution of the Soviet Union has ushered in a new era. With the Cold War arrangement no longer in place, relations between the US and friendly nations are being subject to redefinition. In the arms trade, the post-Cold War era has produced expanded opportunities for recipient countries, opening new and autonomous paths for defense acquisition. For the Republic of Korea (ROK), a traditionally steadfast recipient of US weapons and weapons technology, this has resulted in the emergence of alternative sources for arms procurement. Thus, the supplier-recipient relationship between the US and ROK, traditionally dominated by US supplier control, is beginning to take on more of a supplier-customer orientation. This thesis sought to comprehensively examine ROK weapons development and acquisition policy through the post-Cold War period. Historical developments surrounding the US-ROK arms trade relationship were thoroughly examined and a case study of the ROK's surface-to-air missile defense project (SAM-X) was performed to provide an understanding of US-ROK relations in the post-Cold War environment. Results from the research conclude that, in terms of arms development and acquisition, a more productive course can be set for future dealings between the US and South Korea. Through a better understanding of the intent and direction of ROK policy, it is possible for the US and ROK to settle into a win-win arrangement.

The Armed Forces Communications and Electronics Association (AFCEA) Award

(Presented to a student in the Graduate Information Resource Management program based upon exceptional scholarship, high qualities of character, initiative and leadership)

Title: *Determining the Characteristics of the Air Force Telecommuting Program*
Author: Captain Joseph Wolfkiel
Advisors: Professor Robert Steel and Major Michael Morris
Sponsor: AF/DPC, Washington, DC

This thesis explores advantages and disadvantages to be realized from telecommuting, along with developing a linear regression model that identifies factors correlated with preference for telecommuting among Air Force personnel. This thesis uses a stated preference model derived from existing telecommuting research to characterize the factors impacting the preference for civilian, officer and enlisted Air Force personnel. The regression models developed showed that factors affecting telecommuting preference were different among different sub-samples. Two factors were universal across the sample. Those were "Amount of Telecommuting Job Allows," and "Allow More Work Done." These two factors gave R-squared values of over 0.39 for each major sub-group in the sample. Another significant finding was that telecommuting preference was significantly greater than the amount of telecommuting the job allowed for the entire sample. The discussion includes tables and text, for use by decision makers, describing cumulative amounts of the sample who felt their jobs would allow each amount of telecommuting, along with potential advantages and disadvantages for that amount of telecommuting. This research showed that a linear method can be used to model telecommuting preference and obtain statistically significant results.

Society of Cost Estimating and Analysis Award (SCEA)

(Thesis which best qualifies as an outstanding research effort and as a significant contribution to the development and /or application of cost analysis, cost estimating or contract pricing techniques)

Title: *Manned Versus Unmanned Reconnaissance Air Vehicles: A Quantitative Comparison of the U-2 and Global Hawk Operating and Support Costs*
Authors: Captain Brian Kehl and Captain Michael Wilson
Advisor: Lieutenant Colonel Terry Adler
Sponsor: ASC/RAV, Wright-Patterson AFB OH
(See Dr. Leslie M. Norton Pride-in-Excellence Award)

(Continued on bottom of page 42)

Career and Personnel Information

Joint Assignments for Logistics Officers

Have you ever considered a joint assignment? Wondered about how the joint assignment process works? Wondered about the pros and cons of a joint assignment? This article answers those questions and more.

The Goldwater-Nichols Department of Defense Reorganization Act of 1986, Title X: (1) established the mechanism to ensure quality officers from all of the Services are assigned to joint commands and organizations; and (2) provides the framework for managing joint officer assignments. A major purpose of Goldwater-Nichols is "to improve joint warfighting by training, orienting, educating and assigning high quality officers to joint organizations." It defines the process for assigning officers to joint organizations. This process focuses on joint warfighting commands. As a result, when it comes to assignments they are treated differently from other joint organizations. To understand the difference, you need to understand something about the different kinds of joint assignments.

Kinds of Joint Assignments

There are three kinds of joint assignments: joint critical, joint duty and assignment to a joint organization**.**

Joint Critical. Joint critical authorizations must be filled with a fully qualified Joint Specialty Officer (JSO), unless the requirement is waived by the Chairman of the Joint Chiefs of Staff. JSOs are Service experts in joint operations, organization, functions and missions. They have previous experience in a joint command or organization and have met all the criteria for the Joint Specialty Officer designation.

Joint Duty. This is the most common type of joint assignment.

Assignment to a Joint Organization. Joint duty credit is not given for this kind of assignment.

Officers serving in joint critical and joint duty assignments receive joint duty credit. This simply means the time an officer serves in a joint billet is tracked and recorded permanently in the officer's records. The Joint Duty Authorization Listing (JDAL) provides a complete listing of all joint-credit positions.

Credit for Joint Duty

There are two types of joint duty credit: (1) full-tour credit and (2) cumulative credit. Officers serving a full tour length in a joint duty authorization receive full-tour credit, while those serving less than a full tour, but at least 10 months or more, may receive cumulative credit. Cumulative credit is aggregate and may be combined across several assignments to obtain full-tour credit. Joint credit itself is based on the grade of the position, not the grade of the officer filling the position. For example, a captain filling a field grade joint duty authorization would receive joint credit.

All field grade authorizations in the joint warfighting commands (for example, United States Atlantic Command, United States Central Command, Unites States Pacific Command and United States Special Operations Command) are either joint critical or joint duty billets, and the officers serving in them receive joint duty credit. In contrast, no more than half of the field grade authorizations in joint supporting organizations (for example, the Defense Logistics Agency, Defense Special Weapons Agency or the National Imagery and Mapping Agency) receive joint credit.

Joint Duty Assessment

Goldwater-Nichols requires JSOs assigned to joint critical positions be promoted at the same rate as line officers serving in the Service's headquarters. It also requires officers assigned to joint duty positions be promoted at the same rate as the Service's line officers. For this reason, the records of officers under consideration for a joint critical or joint duty assignment are screened. The vehicle to do this is the Joint Duty Assessment (JDA). The JDA checks for a variety of things: deferred for promotion, Unfavorable Information File (UIF), and the weight management program. Beyond that, the officer should have a master's degree, the appropriate level of professional military education and most importantly, a successful duty history. *Passing* as JDA is in no way a guarantee of future promotion, nor is *not passing* a JDA an indication the officer will be deferred for promotion. The assessment merely ensures the officer is right for the job and the job is right for the officer. As a final check, assignment to either a joint critical or joint duty position requires approval by the Commander or Deputy Commander of the Air Force Personnel Center. In contrast, the applicable assignment branch chief approves most non-joint credit assignments.

Any officer, 0-3 or higher, with a favorable JDA, can serve in a joint position and receive joint credit.

Joint Duty Advantages

One of the major advantages of a joint assignment is stability. Typically, joint assignments in the CONUS are 3-year controlled tours that cannot be curtailed without a waiver from the Secretary of Defense. This, of course, also provides stability to the joint organization as well. Overseas tour length is based on the Service-established number of months. Generally an officer serving an unaccompanied overseas tour will receive cumulative credit, those on accompanied tours will receive full credit. There are exceptions to the full-tour criteria. For example a tour could be curtailed for such reasons as professional military education or command opportunities (commander or deputy commander assignments). For a first joint assignment this could take place at the 24th month and during a second joint tour at the 22nd month. In both cases a waiver from the Secretary of Defense would be required.

A joint tour provides both breadth and depth for career purposes, and selection for a joint assignment is a selective process. Depending on the assignment, the duties can vary significantly. However, joint assignments in the logistics arena provide Air Force logisticians a much broader perspective of logistics in general. Much like the Air Force Intern Program or Logistics Career Broadening Program, a joint assignment is perceived to be, and is, a selective process that will enhance follow-on assignment opportunities.

Other Facts About Joint Duty

- Among all the Services, the Air Force has the greatest number of joint duty requirements.
- Some joint organizations with field grade billets will allow senior captains to fill these positions.
- If you are interested in a joint assignment make sure it is listed on your Officer Preference Worksheet.

With the pending change to the Air Force Assignment System, the Electronic Bulletin Board will be shut off. However, all authorizations (joint or otherwise) can be reviewed via the assignments home page. The listing will include location, grade and level of all positions. It will also indicate when positions will be vacant.

More information concerning joint assignments can be found on the World Wide Web at:

DoD Joint Regulation: http://web7.whs.osd.mil/dodiss/instructions/instruc2.htm

Goldwater-Nichols Act: http://www.law.cornell.edu/uscode/10/ch38.html

New Assignment Sytem: http://www.afpc.af.mil/assignments/oas/oasindex.cfm

Joint Assignments/Officer Management: http://www.afpc.af.mil—Joint Assignments

CANDID VOICES

AFLMA—A Well Kept Secret

Not too long ago, I heard two words that, when combined in the same sentence, would frighten any junior officer—*MPC* (as in the Military Personnel Center) and *non-volunteer*. I had asked for and received an education delay to finish my master's degree. I was nearing the completion of the degree and rapidly approaching four years time-on-station. I was checking the online assignment system every day in the hopes of finding the elusive *dream job*. I had already volunteered for three jobs and had not been picked for any of them. What I did not know was that I was the number one lieutenant in the time-on-station category for maintenance officers and MPC was waiting for the clock on my education hold to expire. Then, the phone rang, I answered, and the conversation on the other end went something like this: "Congratulations, you have been selected for a critically important assignment to the AFLMA at Gunter Annex AL." After I recovered from the shock a few moments later, versions of my perfect little myopic world came crumbling down. Two questions begged at me—I am going where? To do what? I am an aircraft maintenance and munitions officer and my job involves a flight line and airplanes. Last time I checked, neither of these could be found at the Gunter Annex.

Up to that time, I felt I was rather good at my job. I had taken airplanes to numerous points around the globe and received outstanding comments. After several conversations with my commander, I reluctantly accepted the job. Well here I am now at the Air Force Logistics Management Agency (AFLMA) located at Maxwell AFB, Gunter Annex AL—and enjoying it. The AFLMA is truly one of the Air Force's best kept secrets. What an idiot I was for even contemplating turning down this assignment. In the short time I have been assigned here, I have come to realize that my education did not end when I received my diploma. I have been involved in a number of exciting research and project efforts. For this I found it necessary to read, examine and study documents and materials I would never have had the time or motivation to review had I been assigned to an operational wing. Remember when I said I was living in my own little myopic world? Through reading *Air Force Doctrine Document 1—Air Force Basic Doctrine*, *Air Force Doctrine Document 40—Logistics*, *Joint Publication 4-0—Doctrine for Logistics Support of Joint Operations* and *Joint Vision 2010*, I have only begun to understand tomorrow's military challenges and how the Air Force will contribute to the overall national strategy.

Ok, you are probably wondering, just as I did initially, What is an AFLMA? What do they do? Who do they work for? How can they help me? The AFLMA is a Field Operating Activity assigned to HQ USAF/IL. We are a logistics problem-solving agency that, using a broad range of functional, analytical and scientific expertise, tackles the toughest problems facing the Air Force. The Agency's mission is to increase Air Force readiness and combat capability by developing, analyzing, testing, evaluating and recommending new or improved concepts, methods, systems, policies and procedures to enhance logistics efficiency and effectiveness.[1] Within the Agency we have five product divisions: Aircraft Maintenance and Munitions, Supply, Transportation, Contracting and Logistics Plans—the same as those found in a typical wing—along with the Logistics Analysis Division. The analysis division provides state-of-the-art and leading edge computer support, analysis and simulation capabilities.

Anyone can submit a proposed project, problem or area for study to the AFLMA, but it should be channeled through the appropriate command LG. All command-level LGs are members of the Logistics Board of Advisors (BOA, an 18-member group of senior Air Force logisticians and officers) and we must have a BOA sponsor for each project. Upon receipt, the proposed study undergoes an extensive preliminary analysis and is submitted to the AFLMA Commander for approval.[2] If we cannot accomplish the project we will suggest other agencies that may be better suited for the task. When a project is accepted for study the project manager assembles a cross-functional team to study the problem. Together these functional experts and analysts ensure project results are sound, logical and practical. A multi-disciplined approach helps prevent functional sub-optimization. We do not want a proposed solution to a maintenance problem to create supply or transportation problems. It also broadens our personnel's experience and helps them adopt a true logistician's perspective. As part of the project effort we regularly update the organization or activity that proposed the study, along with the project sponsor. Upon the completion of the project the Agency provides the project sponsor with a detailed report which outlines the problem, provides a solution or solutions and makes specific recommendations. The sponsor is responsible for implementing the solution or recommendations.

The Agency's key strength is our people. Of the 41 officers and civilians assigned, virtually all hold advanced degrees—several of which are doctorates. Many of our officers and civilians are also graduates of the Air Force Institute of Technology. Just as important, our work force, to include the enlisted members of our team, has extensive and recent field experience. Members of our staff also have extensive numbered Air Force, major command and joint duty experience. Unfortunately, like many other Air Force organizations over the past few years, the AFLMA has had its manning reduced significantly. In just the last four years we have seen it drop from 92 authorizations in Fiscal Year 1994 to 75 in Fiscal Year 1998.[3] By Fiscal Year 2001, the Agency will have an end-strength of 59 authorizations. At present we have 60 people assigned (29 officers, 19 enlisted and 12 civilians).

The AFLMA produces a number of products. These include: process improvement studies, software prototypes, computer models, policy evaluations, handbooks or guides and CD ROM-based products that can be used for a variety of purposes. In 1997, the Agency completed 44 projects. HQ USAF/IL sponsored about 50 percent. Major commands, Air Logistics Centers, the Secretary of the Air Force and the AFLMA Commander sponsored the remaining 50 percent. We also provide consulting support.

To maintain its recognized high standard of excellence and continue providing the highest quality of support to the Air Force logistics community, the Agency has developed strong working relationships with a variety of other Air Force, public and private sector organizations. For example, we continue to work with the RAND corporation in studying the logistic support concepts required for Expeditionary Aerospace Forces; the Logistics Management Institute on supply issues; and Synergy and the Air Force Wargaming Institute to develop and implement logistics play in GLOBAL ENGAGEMENT 98 (GE98, the annual political-military war game sponsored by the Chief of Staff, United States Air Force).

A collateral mission of the AFLMA is to publish the *Air Force Journal of Logistics (AFJL)*, the premier logistics research publication in the Air Force. The *Journal* is a professional, refereed publication addressing logistics issues, ideas, research and information for military aerospace forces. Published quarterly, it is distributed throughout the Air Force, Department of Defense, other government agencies, foreign military forces, US industry and academia. The *AFJL* also produces and publishes a number of other products to includes monographs and books. Three of the most recent were the *Air Force Logistician's Professional Reading list, Sourcing the Competitive Edge–Selected Readings* and *Logistics Dimensions—Selected Readings*.

Well, now that you know a little about the Agency, its mission and its people, you may be thinking, Why use the AFLMA? Five reasons immediately come to mind: (1) depth and breadth of logistics experience; (2) a high level of academic training and research skills; (3) recent field experience and an understanding of the problems field units face; (4) objectivity of the Agency; and (5) cross-functional teams and expertise. In addition, we work closely with the sponsor in defining and redefining what we study and our focus can be both short-term and long-range. On average the AFLMA will finish a project in under six months.

Additional information about the Agency can be found at the AFLMA World Wide Web site—http://www.il.hq.af.mil.aflma/index.html. Abstracts for our current projects and many of our completed studies can also be downloaded from one of several pages.

Notes

1. *Logistics Support Plan, Volume II, Mission Performance*, AFLMA, 1998, 1-7.
2. *Air Force Mission Directive 33*, Air Force Logistics Management Agency (AFLMA), 1 Jul 97.
3. *Air Force Logistics Management Agency Information Brochure*, 1996, 1-12.

Captain Melcher is currently a Project Manager assigned to the Maintenance and Munitions Division at the Air Force Logistics Management Agency.

Have You Thought About—

Any amateur can shove tanks, planes, and infantry around the map; the real business of war is getting gas, ammunition and spare parts to the people that need them, where they need them . . . the tail, in the form of logistics will more and more wag the dog . . . logistics will increasingly become the single greatest impediment to have real combat capability.

Edgar Ulsamer, Air Force Magazine, Dec 83

Stealth Fighter Avionics: 2LM Versus 3LM

Captain Robert L. Mason, USAF

On the first night of Operation DESERT STORM, the public became aware of a unique aircraft that could sneak past enemy radar and bomb targets with pinpoint accuracy. Though the public had vague knowledge of the F-117A, the aircraft's capabilities were largely unknown. Now a recognized political and military tool, the F-117A has been used several times since. The 49th Fighter Wing (FW), located at Holloman AFB New Mexico, has operated the aircraft since 1992 and has spent much of that time converting the aircraft from a special *black world* or very secret operation to a normally-managed tactical aircraft. Much of the effort has been in logistics, specifically repair capability. With the introduction of improved avionics capabilities, the Air Force is in a unique position to determine the best type of logistics support for F-117A avionics. This article discusses the process the wing used to recommend appropriate future repair capabilities. A brief review of the Air Force's conversion from Three Level Maintenance (3LM) to Two Level Maintenance (2LM) will help in understanding the decisions leading to the 2LM philosophy adopted by the Air Force.

Coronet Deuce and the Rand Study

In 1992, the Tactical Air Command (TAC) commissioned the Rand Corporation to conduct a study on the feasibility of implementing an alternative maintenance structure for F-16 avionics. The Rand Study concluded that a new maintenance concept would save resources and still meet all the Air Force's needs.[1] TAC also conducted studies of their own called the Coronet Deuce Exercises. In 1993, TAC declared these exercises a success.[2] Working with the Air Force Material Command (AFMC), they began the Air Force's 2LM program. All TAC units, some Strategic Air Command (SAC) units and eventually all Air Force units began converting to 2LM from 3LM. F-117A avionics maintenance remained an exception and is still largely 3LM today.

The Stealth Fighter Program

The F-117A was originally designed and built deep in the black world and was kept completely secret for about 10 years. In 1981 the Air Force contracted for 29 aircraft.[3] This number was increased to 59 a year later.[4] By Operation DESERT STORM, the F-117A was a proven aircraft, and though its existence was public knowledge, its development and how its systems worked was still cloaked in secrecy.

Since the aircraft was not designed to ever be in the normal *white world*, provisioning decisions were different from those of a normal aircraft program. When the aircraft was initially manufactured, so were a considerable quantity of spare parts, many of which are still in a warehouse at McClellan AFB CA and then soon Palmdale, CA. Between Lockheed Martin and the Air Force, the aircraft was to be completely self-sufficient and if not completely outside the normal Air Force logistics system, at least not easily visible from within. Parts not common to other systems were assigned a non-descriptive (ND) stock number, invisible to non-F-117A users. As the program emerged into the white world, the ND numbers stayed. A few years later, when the EXPRESS[5] system was introduced, those F-117A specific parts were not included in the database. They were kept separate and tracked by the system program office (SPO) in a Lockheed Martin-managed database called Nighthawk.

Though not a unique aircraft in the realm of avionics, many of the components have been modified from other aircraft and are different enough to require modified test equipment. As an example, the aircraft uses the same ultra high frequency (UHF) radio as every other aircraft in the inventory but the power requirements are different, making modification of normal test equipment necessary to test some radio components. These differences made the F-117A program somewhat unique and difficult to support within the established depot system and led to retention of 3LM capability, while the rest of the Air Force was converting to 2LM. For that reason, our completed study of conversion to 3LM is significantly different from the 1992 Rand report and Coronet Deuce exercises.

Another unique aspect of the aircraft is a new management program the F-117A SPO is testing known as the Total System Performance Requirement 800 or simply TSPR 800. Under TSPR 800, most F-117A system management responsibilities are contracted to Lockheed Martin who, in Fiscal Year 1999, will begin performance on a fixed-price contract.[6] One of the management functions is accountability for the repair cycle. In the past, Lockheed Martin has been responsible for repairs that were not possible at base-level; management of assets was the SPO's responsibility. As mentioned earlier, F-117A unique parts are not loaded in EXPRESS and quite possibly never will be. In the future, Lockheed Martin will make a database available to wing customers to provide some visibility of assets in the repair cycle. We believe Lockheed Martin's market focus will help gain control of the repair cycle and drastically reduce cycle time.

Determining What the Program Needs

With all this in mind, the 49th FW Logistics Group Commander directed a study to determine what capability was really needed and what we had that was excess or inefficient. To accomplish these goals we needed to gather data covering the spectrum of avionics repair, from failure rates to the repair cycle. In examining this data, both from within the wing and from the depot and contractors, we obtained some surprising results. Repair cycle times for assets processed for repairs off base were incredibly long: some process times were over 200 days, so assets were in some stage of the repair cycle, unavailable to the wing, for almost two-thirds of a year.[7] What was even more amazing was that we could not find anyone who knew how to break down that cycle time. Other than what was tracked at base-level through the Intermediate Repair Enhancement Program (IREP),[8] we were unable to quantify how much time the asset was spending in repair versus inbound or outbound queue times.

Cycle time reduction was a major portion of the Coronet Deuce studies accomplished by TAC. What Coronet Deuce did not seem to address in much detail was the effect of 2LM on a wing's ability to deploy and operate in a contingency environment. *AFI 21-130* clearly states that

> To date, we have not identified a simple methodology for capturing the impact of a repair level decision on the in-commission rate for an equipment item or aircraft availability rate for the weapon system.[9]

When determining F-117A needs, it was essential that any change in repair philosophy not adversely affect mission readiness, so a primary concern was the effect of not deploying avionics back-shop repair capability and relying on express shipping would have on wartime sortie rates. Our experience in Kuwait was fairly positive in maintaining readiness without back-shop repair; however, we had to consider two relevant factors. First, our presence in Kuwait has not involved a full squadron sustaining wartime sortie rates. Though utilization rates were higher than at home station, flying still more closely resembled peacetime. Second, after two years of operations in Kuwait we have been able to reduce retrograde (items returning for repair) shipping time to about eight days, though that was only after considerably close management of individual assets. There is no reason to believe we can expect to do as well when the thrust of transportation is on deploying forces.

In order to determine what maintenance capability would be required in the field, we first had to determine what aircraft sortie rates would result during a contingency. We could not find a good model to tell us this in a way that was meaningful so we created our own model. The model is in two parts. The first part determines spares required for support of the 2LM concept and the second for support of a 3LM concept. Some of the factors in the formula were extremely variable and were based on our evaluation of available data. Actual required sortie rates are classified. To keep the study unclassified, we created figures based on experience during Operation DESERT STORM. The two formulas for the model are:

$$(2LM)*S_r = \frac{TT + RCT}{MTBUR/DFH}$$

$$(3LM)*S_r = \frac{TT + RCT}{MTBF/DFH}$$

Required Spares (S_r)—The total number of spare line replaceable units (LRUs) required to support a contingency. This represents the total number of spares required in the repair cycle, not just base supply or deployed kits.

Expected Transportation Time (TT)—This is the time to transport the LRU to the repair source and return it to a contingency location. This time is set at 30 days based on our experiences with 49th FW deployments to Kuwait. We found that towards the end of our last deployment, the retrograde transportation time had dropped to about eight days.[10] That time represents over 150 days of very proactive work on the retrograde cycle and does not include time to ship into the theater. As the Air Force works to meets the strategic planning goals, these times should decrease.

Repair Cycle Time (RCT)—This represents the time, in days, an LRU is in the repair cycle to include time at the depot or contractor repair facility. It was produced by the LRU's item manager.

Daily Flying Hours (DFH)—This is the total hours flown over a 24-hour period. Several assumptions were made and were based on previous experience in Southwest Asia. The sortie rate is set at 1.5 sorties per aircraft/per day with an average sortie duration of three hours—81 hours per day for an 18-aircraft deployment. The F-117A performed at these rates during Operation DESERT STORM.

Mean Time Between Unscheduled Repair (MTBUR)—This represents the number of operating hours between LRU removal from an aircraft. If there is no base (deployed) level capability, this is equal to the number of LRUs consumed. MTBUR is calculated by dividing flying hours by LRU total.

Mean Time Between Failure (MTBF)—This represents the number of operating hours between times when an LRU is repaired in the shop and is calculated by dividing flying hours by the bench checked serviceable rate.

Can Not Duplicate Rate (CND)—This represents the number of times LRUs were removed from aircraft and no discrepancy was found in the shop. The CND rate is compared to the repeat rate (bad actor) to determine if CNDs are valid. A high repeat rate (there will always be occasional repeats) would suggest that back-shop procedures were flawed. The wing has historically maintained a repeat rate well below one percent so we considered the CND rate valid. As long as the wing maintains 3LM back-shop capability, the cost for CNDs is in man-hours to pull, test and reinstall the LRU and the cost to run the test equipment. As LRUs transfer to 2LM, CND costs become greater as transportation costs and depot/contractor repair costs must be considered. With ND coded stock numbers and the fixed-price provisions of both the TSPR 800 and a similar contract with Raytheon, those costs become contractor, not Air Force issues. CND rates are included in Table 2 as they are useful in determining the value of maintaining a 2LM screening capability.

Percent Base Repair (PBR)—The number was taken from the Standard Base Supply System (SBSS) database. The number in Table 2 represents a snapshot in time and is quite variable, but it is representative of our capabilities. We confirmed these times with manual records kept by the avionics flight.

The 2LM formula yields the number of LRUs we believe must be available in the total pipeline, under current conditions, to support contingency operations. This includes LRUs in depot or vendor repair, awaiting action, in transit and in kits. Table 1 shows this number in the S_r (2) column.

The 3LM formula indicates the number of LRUs we believe must be available in the total pipeline, under current conditions, to support contingency operations with deployed shop capability.

LRU	TT	RCT	MTBUR	MTBF	DFH	Sr(2)	Sr(3)
Turret	30	5	142	148	81	20	19
Weapons System Computer (WSC)	30	157	770	1680	81	20	9
Projection Display Unit (PDU)	30	182	352	616	81	49	28
Color Multipurpose Display Indicator (CMDI)	30	157	448	474	81	34	32
Flight Control Computer (FLCC)	30	160	493	587	81	31	26
Navigation Interface Autopilot Computer (NIAC)	30	137	513	1232	81	26	11
Flight Control System Panel (FCSP)	30	157	316	725	81	48	21
Display Processor (DP)	30	255	316	493	81	73	47
Expanded Data Transfer Module (EDTM)	30	200	232	385	81	80	48
EDTM Interface Unit (EDTMIU)	30	237	187	316	81	116	68
Data Entry Panel (DEP)	30	200	880	12320	81	21	2
Map Digital Processor (MDP)	30	187	6160	12320	81	3	1
Mass Storage Device Electronics Unit (MSDEU)	30	157	8213	12320	81	2	1
Control Stick	30	157	12320	12320	81	1	1
Throttle Grip, Left	30	157	12320	12320	81	1	1
Throttle Grip, Right	30	157	560	821	81	27	18
Armament Control Panel (ACP)	30	152	2464	12320	81	6	1
Weapons Load Panel (WLP)	30	263	4107	12320	81	6	2
Weapons Interface Panel (WIP)	30	237	12320	12320	81	2	2
Computer Control Panel (CCP)	30	100	12320	12320	81	1	1
Discrete Interface Box (DIB)	30	67	6160	12320	81	1	1
Resistor Interface Box (RIB)	30	*	12320	12320	81	*	*
UHF Radio	30	157	237	246	81	64	62
TACAN RT	30	*	1232	1369	81	*	*
TACAN Adapter	30	*	6160	12320	81	*	*
TACAN Control Panel	30	157	1232	2464	81	12	6
ILS RT	30	*	2464	4107	81	*	*
ILS Control Panel	30	244	4107	6160	81	5	4
IFF RT	30	273	474	684	81	52	36
IFF Control Panel	30	100	4107	4107	81	3	3

* These figures were unavailable from the item managers. Sr(2) and Sr(3) could not be calculated for these items.

Table 1. Required LRUs in the Pipeline—2LM and 3LM

Again, this includes all LRUs in the entire pipeline. Table 1 shows this number in the S_r (3) column.

We used flying hours instead of sorties for these calculations. All failure data for LRUs is calculated using flying hours, as using sorties would mean converting hours to sorties, yielding approximately the same results.

Table 2 provides a fairly definitive view of which LRUs should be converted to the 2LM concept and where we should concentrate our capability for those that remain 3LM.

Current Capability Versus Real Need

To provide a deployable avionics repair capability, large, very heavy containers (vans) were modified to house the necessary test equipment to screen and perform post-repair tests on virtually all the aircraft's avionics components. A full squadron deployment requires 13 pallet positions to move this equipment. In the earlier days of the program this heavy load was considered an acceptable cost for such a unique capability, but today, we cannot assume airlift will be readily available in sufficient time to deploy this capability before readiness spares are consumed. Also, the program has enjoyed several upgrades to the aircraft's avionics suite, including considerable improvement in component MTBF. Finally, with the current push to down size and outsource, we must either find the most efficient means of managing our back-shop capability or we might find ourselves with less capability than is prudent. The Department of Defense has laid out a very comprehensive Logistics Strategic Plan that says we must ensure readiness for war while becoming smaller and more efficient.[11]

An interesting discovery is that the infrared turret, the heart of the F-117A bombing system, is a good candidate for 2LM. This has made us take a serious look at what the numbers really mean as the turret is the number one avionics maintenance driver on the aircraft. Additionally, current turret screening and trouble-shooting capability is quickly fading away as the test equipment is old and replacements are no longer available. The program has spent a considerable sum to develop new repair and screening capability for the turret and associated systems and conversion to 2LM would relegate years of work and millions of dollars to the scrap heap. This is a very difficult decision and is still being discussed at the time of this writing.

Another significant fact is that capability to repair communications and radio navigation systems is very beneficial to the wing. Though some of these components are ND coded, some are in EXPRESS. We can see the EXPRESS items are in short supply Air Force-wide and yet the repair capability that used to exist in every wing before conversion to 2LM is, in many cases, no longer available. Due to the unique configuration of the F-117A systems, we still have that repair capability and are not having the problems seen in some other weapons systems. During our most recent deployment to Southwest Asia we could have repaired 100 percent of the breaks in these systems if the capability had been deployed. Two units tested *could not duplicate* and 10 were repaired in the shop.[12] We do not have a deployable repair capability at this time so we investigated two options. First, the Mobile Electronic Test Set (METS), currently used for the F-15E, performs all the functions of the home station manual test set but faster and with added capability we currently do not have. The added capability is not really needed and the almost $2M price tag discouraged this option.

The second option was to procure additional manual test sets similar to the one we currently have. As many of these test sets were turned-in to the depot during the 2LM conversion, we are procuring them at no cost to the Air Force. We feel this will give us significant capability to repair components without sending them back to home station. We realize shop replaceable units

LRU	Sr(2)	Sr(3)	PBR	CND (%)	AVAILABLE SPARES	2 vs 3
Turret	20	19	99	7	38	2(1)
Weapons System Computer (WSC)	20	9	99	52	3	3
Projection Display Unit (PDU)	49	28	62	9	35	3
Color Multipurpose Display Indicator (CMDI)	34	32	90	2	25	3
Flight Control Computer (FLCC)	31	26	91	8	27	3
Navigation Interface Autopilot Computer (NIAC)	26	11	91	42	23	3
Flight Control System Panel (FCSP)	48	21	85	38	39	3
Display Processor (DP)	73	47	74	10	11	3
Expanded Data Transfer Module (EDTM)	80	48	77	28	34	3
EDTM Interface Unit (EDTMIU)	116	68	69	15	31	3
Data Entry Panel (DEP)	21	2	35	36	25	2+
Map Digital Processor (MDP)	3	1	99	50	21	2+
Mass Storage Device Electronics Unit (MSDEU)	2	1	99	33	26	2+
Control Stick	1	1	99	0	18	2
Throttle Grip, Left	1	1	100	0	14	2
Throttle Grip, Right	27	18	0	9	27	3
Armament Control Panel (ACP)	6	1	25	20	17	2
Weapons Load Panel (WLP)	6	2	42	0	32	2
Weapons Interface Panel (WIP)	2	2	0	0	14	2
Computer Control Panel (CCP)	1	1	90	0	12	2
Discrete Interface Box (DIB)	1	1	0	50	14	2
Resistor Interface Box (RIB)	*	*	0	0	27	2
UHF Radio	64	62	99	2	14	3(2)
TACAN RT	*	*	84	0	904	3(2)
TACAN Adapter	*	*	99	50	436	3(2)
TACAN Control Panel	12	6	99	2	16	3(2)
ILS RT	*	*	99	40	24	3(2)
ILS Control Panel	5	4	66	0	5	3(2)
IFF RT	52	36	88	19	133	3(2)
IFF Control Panel	3	3	99	0	16	3(2)

* These figures were unavailable from the item managers. Sr(2) and Sr(3) could not be calculated for these items.

Table 2. Needs Results (LRUs)—2LM Versus 3LM

(SRUs) must be procured to support this capability, but they are smaller and much easier to ship than the entire LRU. This capability will add no additional size to our deployment package.

Now that we knew what repair capability to retain, we needed to determine how to best configure that capability. The current system, Consolidated Automatic Test Equipment (CATE), gives us all the capability we need, but is much too large for today's deployment scenarios. We're investigating CATE downsizing in order to reduce its deployment footprint to two pallet positions, but have not developed a cost estimate. This, combined with the manual test station, will reduce required pallet positions by 10.

Another possibility is to adapt the Improved Avionics Intermediate Station (IAIS) currently used by F-16 units. It is already compatible with some of our LRUs, though there are software incompatibility problems. The CATE system operates on a C++ based program while IAIS uses the more traditional Abbreviated Test Language for All Systems (ATLAS). We have been unable to find a compiler that would allow C++ and ATLAS to work together, so use of IAIS would require considerable rewrite of code. Additionally, the IAIS would cost about $5M.

Summary

As the F-117A did not develop along the same path as most modern aircraft, there has been room for considerable change in logistics support since the beginning of the program. This unusual development has given us a rare opportunity to create a method to meet the Air Force's logistics goals with unit level planning. The 49th FW's study demonstrated that both savings and increased combat capability can be realized if decisions are based on a combined 2LM/3LM approach to avionics maintenance, as well as a combination of factors including unit readiness rather than strictly cycle time and cost. There are still difficult decisions to be made and we are approaching them in a slow, fact-based manner as we know what we implement now will impact the program for the rest of its service-life.

Notes

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2. Tactical Air Command, *Coronet Deuce III Executive Summary*, Langley AFB VA: 1992, 2.
3. Rich, B. and Janos, L., *Skunk Works*, Boston, MA: Little, Brown and Company, 1994, 89.
4. *Skunk Works*, 91.
5. Execution and Prioritization of Repair Support System (EXPRESS) was developed for various reasons but allows much greater asset visibility in the repair cycle for the limited number of aircraft components currently loaded in the system.
6. Lockheed Martin Skunk Works, *Total System Performance Responsibility, F-117A Weapon System*, Palmdale, CA: 1998, 2.
7. Mason, R., Bear D., et al., *Avionics Capabilities and Future Changes Part 2, 49th Maintenance Squadron*, Holloman AFB NM: 1998, 4.
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9. Department of the Air Force, *AFI 21-130, Technical Analysis to Determine Criterion for 2 vs 3 Level Repair*, 1998, 4.
10. Hovland, T., *Retrograde Pipeline Summary Report*, Holloman AFB NM: 1998, 3.
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At the time of his writing, Captain Mason was the Maintenance Supervisor at the 49th Maintenance Squadron, Holloman AFB, New Mexico.

The War in the Persian Gulf

Captain Thomas J. Snyder, USAF
Captain Stella T. Smith, USAF

Editor's Note: The following article is an edited version of the last part of Chapter 3 of The Logistics of Waging War, Volume 2, US Military Logistics, 1982-1993, The End of "Brute Force" Logistics, which was recently published by the Air Force Logistics Management Agency. The first part of Chapter 3 was published in Volume XXII, Number 2. This monograph chronicles logistics efforts and operations from 1982-1993 and examines the final chapters of what has been aptly called the era of "brute force" logistics. Volume 2 is available in hard copy through the Air Force Journal of Logistics or via the World Wide Web (http://www.il.hq.af.mil/aflma/lgj/lww2.html).

Theater Logistics

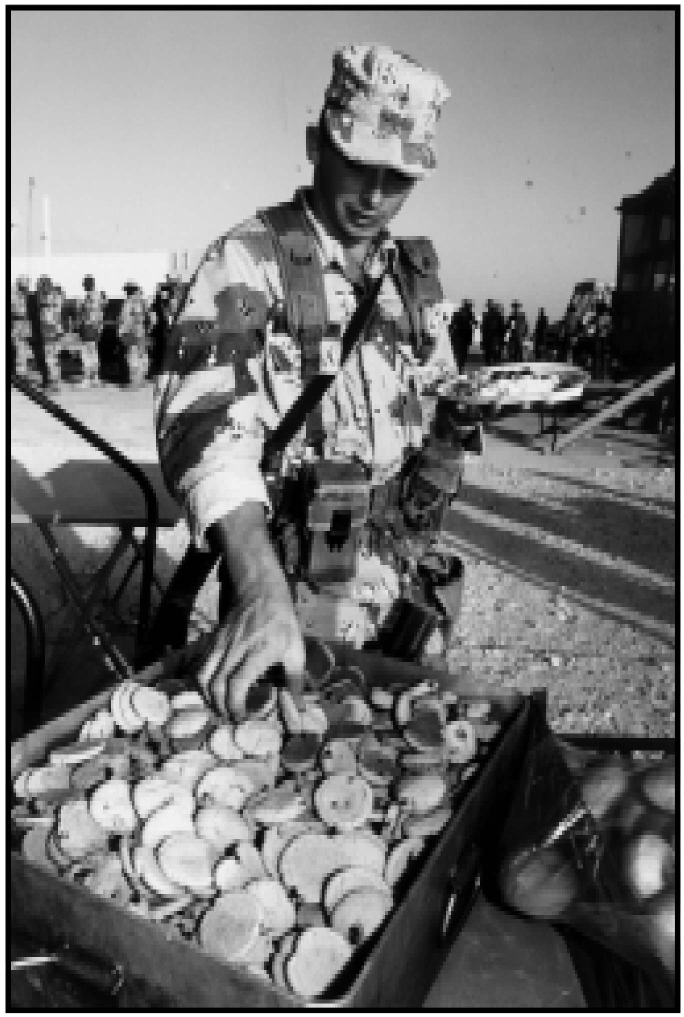
Due to the pressing urgency of the initial deployment to the Gulf, and a strong possibility that Iraqi forces might move on Saudi Arabia before a substantial US defensive presence could be established, the decision was made early on to deploy combat units significantly in advance of their supporting units. This meant that at the operation's onset US forces found themselves without their standard established logistics structure. Eventually, the size of the US logistics force in the region would grow to over 40,000 with about 60 percent coming from the Reserves or the National Guard.[1]

To facilitate a secure logistics base in the Gulf Theater, support personnel built roads and laid pipeline. Supplies needed by combat troops were transported forward to strategic locations near the front lines in order to make them more accessible to the troops that needed them. US forces even went so far as to build a helicopter refueling strip inside the Iraqi border to provide for faster servicing and turn-times for combat helicopters involved in close air support of allied forces.[2]

A critical difference between supporting DESERT SHIELD and supporting a combat force of the same size in a European theater was the road system. The challenge in Saudi Arabia was getting the critical tonnages of food, fuel and bullets from the APODs and SPODs forward to the combat maneuver units.[3]

Food, Subsistence and Rations

Military commanders have often subscribed to the notion that the quality of the food available to fighting forces in the field will impact their performance in combat. For this reason, providing adequate rations for military personnel in the field is of paramount concern to the managers of the supporting logistics system. Using mobile kitchen facilities, existing dining facilities and host nation contracted support, the Department of Defense was generally able to meet this goal for the majority of deployed personnel. However, due to their locations, some Army and Marine Corps units had substantial difficulties obtaining a variety of foodstuffs and alternatives to meals-ready-to-eat (MRE) rations.



US personnel visiting the traditional military *chow line*. The variety and type of rations provided depended on where the unit was deployed and the food preparation facilities available. (Official Air Force Photo)

Food Services

Throughout the theater of operations, commanders were given significant latitude to provide the highest quality rations they could obtain given the constraints of the existing environment.

The variety and type of rations provided depended entirely on where a given unit was stationed and the type of preparation facilities available in the area. Air Force units, enjoying the relative benefits of operating from stable, fixed locations, generally enjoyed fresh food supplied by host nation contractors. Army and Marine units, by nature of their constantly changing positions and tactical environments, had to subsist mainly on MREs and occasionally tray pack T-rations. Fresh food was made available whenever the situation permitted, with deliveries of limited quantities of morale-boosting favorites such as fresh fruit delivered by whatever means of transportation happened to be operating in the area.

In less than a month after President Bush committed US troops to Saudi Arabia, the Defense Logistic Agency had shipped 15.6 million MREs and 2.6 million tray-pack rations to the theater. They also sent 10 million loaves of bread, 6.3 million pounds of meat, 4.9 million pounds of fish and 2.8 million pounds of fresh fruit and vegetables.[4]

All the Services did their best to provide fresh or frozen foodstuffs and other supplements such as fruit, juices, soft drinks and the like from facilities located throughout the region. Each Service developed a daily feeding plan, outlining the types and quantities of meals supplied to its troops in the field. The Army feeding plan called for one MRE and two hot meals to be provided to each soldier daily. Illustrating the difficulties encountered in theater, the Army was never able to meet this plan due to the inability of producers in the United States to meet the actual demand for T-rations that materialized during the Gulf War. As a result, the Army relied on MREs and B-rations, which, in-turn, prompted a shortage of the components for B-rations, in particular meats and vegetables. Here again, the cause was the inability of the domestic producers to meet the unanticipated demand for these components by deployed US forces.

In response to these shortages, the Army developed and adopted meals, off-the-shelf, ready-to-eat (MOREs)—a product generally well accepted by the troops and often a welcome change from the stock MREs the majority of forward employed ground troops had grown accustomed to.

Recognizing the importance of food to maintaining troop morale and the potential ill effects of the limited availability of diverse rations, the *Wolfburger* stand was developed. The brain child of a warrant officer aide to Army Major General Pagonis, the *Wolfburger Wagon* was really nothing more than a military adaptation of the portable hamburger and hot dog stands commonly experienced by the American public each summer at local fairs. Towed to forward locations, often in close proximity to the actual front lines, these mobile kitchens provided a variety of short order foods centering on fare such as hamburgers, hot dogs and french fries. A significant hit with the troops, Wolfburger stands proved an innovative and morale-boosting means of improving the quality and variety of the meals received by Army personnel in the theater.

The Army recognized the limitations of its troop feeding plans. Specifically, the operation highlighted the inability of the industrial base to respond effectively to increased demand on short notice. Under circumstances of more direct hostile action by opposing forces, reliance on more traditional prepackaged foods such as MREs is expected. However, the importance of good food to supporting the morale of troops exposed to extended periods of combat means that alternative rations should be a significant planning issue for future combat operations.

The Marine Corps feeding plan was similar to that of the Army in that it, too, called for one MRE and two hot meals daily. Within one week of arrival in theater, the Marine Corps was serving its first hot meal. Within a month, the majority of Marine Corps personnel were receiving two hot meals a day.

Rations for Air Force personnel were far more abundant and varied than those available to their Marine Corps and Army counterparts. Relying initially on rations included in prepositioned storage sites, managers had these rations moved to operating locations in advance of the arrival of the forces. These rations, consisting primarily of MREs and B-rations, provided Air Force personnel with a sizable initial operating stock until other ration sources became available. Thus, Air Force units never faced any real possibility of a shortage of quality rations. The ready availability of prepositioned MREs, B-rations and Harvest Falcon kitchen equipment sets provided the Air Force with a substantial advantage in food service capability during the early phases of employment operations.

When it came to the actual preparation of field rations by military food service personnel, the different Services experienced varying degrees of success with existing field kitchen equipment.

When it came to the actual preparation of field rations by military food service personnel, the different Services experienced varying degrees of success with existing field kitchen equipment. The Army relied heavily on a mobile field cooking trailer that proved extremely fragile and worked well only in the most ideal of circumstances. The trailers offered only limited protection from the environment and sand was constantly finding its way, not only into the internal workings of the unit but, to the dismay of the troops, into the food being prepared. Food heaters were also ineffective or failed to work at all.

The Air Force's experience with its mobile field kitchens was somewhat better. Relying heavily on Harvest Falcon field kitchens, the Air Force's main problems stemmed from a shortage of readily available spare parts for the units. When equipment on the units failed in the field, replacement parts, readily available in the States, were difficult to obtain as they had to be procured through regular supply channels and then compete for transportation among the plethora of higher priority cargo moving to the theater. In this vein, the Marine Corps had a similar experience as field kitchen equipment failed at higher than anticipated rates due to the unaccustomed length of use and the degradation induced by the blowing sand and generally harsh climatic conditions in which the equipment was utilized.

The Air Force replenished B-rations from theater stocks on an as-requested basis. In addition, the relatively fixed locations at which the majority of Air Force personnel were billeted allowed Air Force food service management to rapidly transition the existing feeding capability to an almost cafeteria-style operation using host nation contractors. Such contractors provided fresh food on a daily basis, a wide selection of beverages and personnel for clean up and maintenance of dining facilities. In some instances, host nation personnel also provided food preparation and service. While generally allowing for the highest levels of food service and variety of fare available during the conflict, reliance on contracted personnel also led to unanticipated problems. At several bases, Air Force personnel were left with

Stocks of potable water have always been a critical factor for military operations and the Gulf War was no exception. In this photo bottled drinking water is moved from central storage to troops in the field. (Official Air Force Photo)

During the Gulf War the US deployed two naval hospital ships, the USS *Comfort* and the USS *Mercy*. The *Mercy* is seen in this photo. (Official Air Force Photo)

Medical personnel treat a troop overcome by heat exhaustion and dehydration. (Official Air Force Photo)

no way to prepare meals when contracted personnel left the installation after a warning of impending chemical attack was received. This situation was only alleviated when contractor personnel returned and were provided with appropriate protective equipment.

While there were shortages of certain types of rations during the initial phases of the deployment, one type of ration that was never in short supply was MREs. In fact, due to the relatively short duration of DESERT STORM, a surplus of MREs and B-rations developed. By April 1991, the Army's Material Management Center at Dhahran, the theater manager for food items, projected that a minimum of 16 million MREs were available in theater. The Air Force found itself with 50 to 70 40-foot shipping containers containing an estimated one million meals valued at $4.5M. The Marine Corps likewise reported it had over 3.5 million MREs available in theater and another 2 million available aboard supply ships in the region.

Given the abundance of MREs, Army Support Command actively encouraged soldiers rotating back to the US at the conclusion of hostilities to carry home at least a 3-day supply. This not only helped to eliminate the immediate stocks of forward deployed rations, but also minimized the need to feed large numbers of transiting Army personnel during sometimes lengthy delays at intermediate points on the route back to the United States. The remainder of food in country was designated for transfer to the World Bank for redistribution to needy countries. The majority of B-rations were used to feed Iraqi refugees during subsequent humanitarian assistance operations. The US Marines, ever resourceful and recognizing the Army's responsibility for overall management of food within the theater, simply transferred its stocks to the Army for disposition.

Water

Distributing water beyond central water points to individual units is a transportation intensive operation.

In addition to water intended for consumption, water to support laundering of hospital linens generated a considerable additional demand. For example, a 400-bed evacuation hospital requires 28,000 gallons of water per day.[5]

The US Army served as the chief water bearer for the four Services. That responsibility ultimately required the Army to provide 20 gallons a day per soldier, sailor, airman and marine, as well as for on-site civilian advisors and contractors. The per-person daily allotment included six gallons for drinking, plus water for cooking, washing, hygiene and vehicle radiators.[6]

In addition to water obtained from approved host-nation supply sources, additional quantities were obtained through the use of reverse-osmosis water purification units capable of producing potable water from fresh, salt, brackish and chemically contaminated water supplies. Production capacities for these units ranged from 9,600 gallons per day for smaller units to 110,000 gallons per day from the largest. Local distribution was provided through an intricate network of water *buffaloes*, drums, bladders and miles of hose.[7] Long-haul trucking of potable water was used where no local source of supply existed or could be developed. In many cases portable water purification units were used to minimize transportation requirements.

Medical Support

One of the most prevalent complaints encountered by deployed medical service personnel were various intestinal disorders associated with acclimatization to the food and environmental conditions in the theater.

Occasional incidents of heat exhaustion and dehydration were also encountered as well as several run-ins with venomous insects and snakes found throughout the region.[8]

A central mail facility handles the large volume of mail generated during the Gulf War. While mail proved to be a definite morale booster during the Gulf War, as it has in all previous wars or conflicts, it did require a substantial amount of airlift to move. (Official Air Force Photo)

Mail

The public outpouring of support for US forces was overwhelming. Schoolchildren, veteran's groups and ordinary citizens were writing letters and sending care packages, tapes and magazines that were shipped by military aircraft through the already congested APOEs. Postal authorities reported that more than 30 million pounds of mail were shipped from the beginning of DESERT SHIELD until Christmas. On 30 November alone, 617,000 pounds of mail was airlifted. As a result, assigning airlift priorities became a much more difficult task.

The defense depots routinely utilized express mail to ship thousands of small parcels to the theater. These parcels competed with standard mail and care packages for limited airlift to the theater. The Desert Express route resolved this conflict, but the logistics of moving hundreds of thousands of pounds of mail remained a major challenge. In order to alleviate the burden of distributing mail to the theater, on 19 January 1991, the Department of Defense requested that well-wishing troop supporters at home stop sending packages to deployed forces and limit mail to letters.[9] By 5 February 1991, the postal service handled 273, 300 pounds of mail per day to Saudi Arabia. At an average of five pieces per pound, that was over 1.3 million items per day. That volume was down from the January high of an average 419,000 pounds per day. The sheer volume of mail flowing to the Gulf region was not the only factor making mail distribution challenging. The situation was further complicated by the constant movement of troops and their units, which significantly increased the difficulty of forwarding the mail to the hundreds of Army, Air Force and Fleet post offices scattered throughout the theater.[10]

In addition to mail handled through formal postal channels, airline flight attendants and pilots began collecting magazines and books to bring over with each flight. Volunteer groups back in the US at units' home stations gathered books and magazines and collected board games and playing cards to be sent over with unit cargo whenever space would allow.[11]

To maintain the morale of deployed troops, especially during the Christmas season, mail was first on the US Central Command's priority list. In one mid-December 1990 report, the cargo diversion team at Tinker AFB reported that over 50 percent of all aircraft departing were loaded with mail.[12]

Petroleum, Oil and Lubricants (POL)

The Gulf War was unique in military history as the first conflict in which any significant percentage of US tanks, ground vehicles, aircraft and ships were powered by the same type of fuel. While not universal, JP-8, a kerosene-based fuel, was used in a diverse range of vehicles. Included were the Army's M1A1 Abrams main battle tank, self-propelled howitzers and Bradley

Fighting Vehicles. The fuel was also used to power Army helicopters and at least one Navy ship with a gas-turbine engine plant. The majority of Air Force aircraft used JP-8 as well.[13] The ability of systems to use a common fuel simplified the logistics of fuel distribution and more importantly provided commanders flexibility to obtain fuel from the most immediately available source. Since it was left to the individual commander's discretion as to which fuel to use, the decision largely rested on what fuel of which type was most readily available in the immediate area. The use of a single fuel, while not essential to the successful outcome of the Persian Gulf War, provided an opportunity to test a concept that could conceivably be vital to future US operations in more fuel-critical theaters.

Harvest Falcon

Initial Harvest Falcon deployments by the USAF included items to support housekeeping and mission-support operations: lighting sets, washers, dryers, shower and shaving units, portable latrines and electrical cable, for example. This equipment provided for immediate needs and aircraft support. Harvest Falcon assets were designed to support up to 750 aircraft and up to 55,000 personnel.[14]

Tent theaters were among the morale, welfare and recreation facilities established to support US personnel during the Gulf War. (Official Air Force Photo)

Morale, Welfare and Recreation

Once the immediate support needs of US forces were attended to, the Services took active steps to improve the quality of life of deployed personnel. The Air Force Commissary Service deployed over 100 personnel to distribute food and run tactical field exchanges.

Mini-exchanges offered a limited supply of toiletries, writing supplies and comfort items. They were stocked and operated by the Army and Air Force Exchange Service while manned by the commissary service as a part of its wartime mission.[15]

Shortages

It is important to note that as supplies moved to the Persian Gulf, depots also received new supplies from vendors and manufacturers at an almost equal rate. Shortages of some items such as MREs sometimes required depots to adopt innovative solutions through the use of similar alternative items. For example, Hormel's Top Shelf™ prepackaged meals were issued until MRE stocks could be replenished.[16]

Attack helicopters at a forward location are refueled. (Official Air Force Photo)

Some items could not be replenished as quickly as they were shipped. Modern sophisticated weapons such as laser-guided antitank missiles (like the Hellfire for US AH-64 Apache attack helicopters) and sophisticated antiaircraft missiles, are not produced in large quantities. Increasing production rates for rapid delivery is difficult because production lines are limited for major components like complex electronics. Other factors that made it difficult for vendors to rapidly increase production rates include limited numbers of skilled workers who assembled components; and the availability of special materials or limited resources.[17]

If the Gulf War had lasted longer, it is unlikely that production could have met demand and permitted restoration of stocks.

The combined problems of limited initial stocks and low production rates meant that it was possible for US and allied forces to run out of certain items. If the Gulf War had lasted longer, it is unlikely that production could have met demand and permitted restoration of stocks.[18]

On 9 January 1991, President George Bush issued an executive order compelling civilian manufacturers to give first priority to the military. At the start of Operation DESERT SHIELD, some government planning experts believed the US possessed less than a ten-day supply of certain critical munitions stocks. The reasons given for such shortages included the Services' preference for high-tech weaponry over the last 20 years, a sharp reduction in orders during the year prior to Operation DESERT SHIELD due to the belief that the Cold War was over, and the fact that the commanders of forces in the Gulf were requesting more ammunition than Pentagon planners had anticipated.

Items in short supply included some varieties of tank and artillery shells, machine-gun rounds, rockets, mortars and other "dumb" munitions with high expenditure rates during combat. In an interview before Operation DESERT STORM, Army Major

Munitions storage and build-up (assembly) facilities were established in a number of locations during the Gulf War. (Official Air Force Photo)

General Paul Greenberg, commander of the Armament, Munitions and Chemical Command, the agency which buys munitions for all of the military Services, reported that shortages existed or were anticipated in numerous ammunition categories. The general went on to state that ammunition requisitions from Central Command forces were averaging about 125 percent of the planned consumption rates for a typical ground war.[19]

In the short run, Gulf force commanders were able to get around these shortages by turning to NATO allies for access to their stockpiles of munitions designed to be interchangeable with US weaponry. While NATO allies were generous in their willingness to provide such support, this was not a panacea. There were technical problems stemming from the environmental differences between Saudi Arabia and Western Europe, and in many cases, this was the first time US equipment was employed with allied ammunition.[20]

By the end of November 1990, the Army had dipped into its European stockpiles for 1,000 Hellfire antiarmor missiles, 3,000 Tow II antiarmor missiles, 4,000 105mm artillery shells and 900,000 rounds of 25mm machine gun ammunition. During the first weeks of DESERT SHIELD, the Air Force requested and received, from Congress, an extra $40M to order 600 additional GBU-27 laser guided bombs for immediate production.[21]

The reason for such shortages will no doubt be the subject of much controversy and debate for years to come. However, one aspect of the problem widely agreed upon is that the Services' preference for high-tech weaponry over so called *dumb* systems has promoted inventory shortages of the less sophisticated, but still vital weaponry. The ultimately successful employment of many high-technology weapons systems in the Gulf War is seen by many as vindicating the Services' desire for more expensive, higher technology systems. The fact that the US has never succeeded in building up a planned 60-day wartime operating stock of required ammunition should be a prime logistics concern inherent in the planning for any future military campaign. Clearly, a mix of both *smart* and *dumb* systems is required due to the wide range of target types and mission profiles encountered on the modern battlefield. The critical question for logisticians will be whether the *correct* balance of weapons types is available and whether the stockpiles of each are sufficient to support protracted combat operations as opposed to the limited combat phase encountered during Operation DESERT STORM.

Uniforms

An item that proved to be of significant concern to deploying troops and in short supply throughout DoD supply channels was the desert camouflage battle dress uniform (BDU). Many servicemen heading to the Middle East found that the desert BDU was unavailable through military supply channels and not stocked in military clothing sales stores. As such, many servicemen were forced to do their own shopping at military surplus stores for such items as the basic desert BDU ensemble, hats with wide brims appropriate for the desert environment and lightweight desert boots designed for the sandy environment of the Saudi Arabian peninsula. Service members really had little choice. They could either choose to buy the uniform themselves or go without. Given the high degree of uncertainty during the initial phases of DESERT SHIELD as to specific threats an individual was likely to encounter and which personnel were likely to become actively involved in a combat environment, a large number of personnel chose to use their own funds to purchase this *issue-item* that was otherwise unavailable through DoD supply channels.[22]

Both the Army and the Marine Corps also had some difficulty with availability and sizing of uniforms, boots and, particularly, chemical defense ensembles. The Air Force experienced many of the same types of problems, but experienced the additional

Army troops wearing green battle dress uniforms (BDUs) board an aircraft for deployment to Southwest Asia. Supplies of the desert camouflage uniforms proved to be a problem during much of the Gulf War. (Official Air Force Photo)

limitation that desert camouflage uniforms were available to only approximately 20 percent of its personnel in theater.

Seen as a way around the long delays associated with massive requisition backlogs, units of all the Services found themselves in the business of *appropriating* or *liberating* needed materials to meet unit needs.

Scavenging War Supplies

To frontline officers, the most adept scavengers became vital to the getting needed supplies that were bogged down in a saturated logistics system. Scrounging and scavenging, as in so many wars before, evolved to a vital art during Operation DESERT SHIELD. Seen as a way around the long delays associated with massive requisition backlogs, units of all the Services found themselves in the business of *appropriating* or *liberating* needed materials to meet unit needs. Units were as apt to *borrow* what they needed from other units of their own Service as they were to commandeer materials from elements of the other Services. In addition to the outright covert raids carried out to obtain needed items, units became involved in an unofficial system of barter and exchange to meet their mission requirements. Thus, unit supply personnel might hold or obtain items needed by other units in order to gain an advantage during future negotiations. While the costs and benefits of this informal logistics system may be immeasurable, the existence of such a system has been an inseparable part of military campaigns throughout history.[23]

The fact that the US was able to successfully deploy . . . should not be taken as . . . proof that it could accomplish the same feat again.

Observations

The fact that the US was able to successfully deploy the necessary forces and equipment to the Gulf should not be taken as an across-the-board proof that it could accomplish the same feat again for future conflicts. Operations DESERT SHIELD and DESERT STORM were unique in a number of respects. First, US forces had an unprecedented amount of time, 161 days, to set up the theater in preparation for combat operations. Setting up the requisite logistics infrastructure and positioning and posturing US forces in the face of active enemy resistance would have been considerably more difficult. Also, the existence of many modern bases, ports and airfields throughout Saudi Arabia lessened the degree of preparation necessary. In fact, the Saudi Arabian ports utilized during DESERT SHIELD and DESERT STORM are some of the best in the world. The Saudis also provided fuel, water, ground transportation, as well as some housing and provisioning support.[24]

DESERT STORM demonstrated that the United States is dangerously short of cargo ships and aircraft needed to get troops and their weaponry from the United States to distant trouble spots in a hurry. As Admiral Butcher stated,

> It's dangerous to use DESERT SHIELD and DESERT STORM as a good example of what we can do in sealift because 47 percent of it came from foreign ships, which might not be available in the next emergency.

Another advantage that the US could not count on in a future conflict, he said, is the use of Saudi Arabia of "the best seaports, the best airports." The foreign support, he stated, brought out not only the help of their cargo ships and planes, but permission to fly through their airspace.[25]

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coalition of forces. By putting nation-specific mission requirements aside and arriving jointly at program goals, cooperative partners gain the benefits of compromise in a finished defense product, which is technologically superior and meets the defense objectives of an allied force.

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Expert Provisioner: The Development and Implementation of a Knowledge-Based Decision Support Tool for RAF Reprovisioning continued from page 19)

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Edwin W. Rawlings Award

(Presented to a student in each graduating class in recognition of exceptional scholarship and high qualities of character, initiative and leadership—the award is named in honor of General Edwin W. Rawlings, one of the Air Force's outstanding leaders in the field of logistics and Commander of the Air Materiel Command from 1951 through 1959)

Recipient: Captain Joseph Scherrer

Louis F. Polk Award

(Awarded for academic achievement, response to academic challenge and ability to apply academic theory to practical matters of national defense management—sponsor: National Defense Industrial Association)

Recipient: Captain John Bell

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Recipient: Capt John Bell

Society of Logistics Engineers (SOLE) Jerome G. Peppers, Jr., Outstanding Student Award

(Outstanding student whose academic record and contributions to the field of logistics are judged superior)

Recipient: Capt Kevin Gaudette